

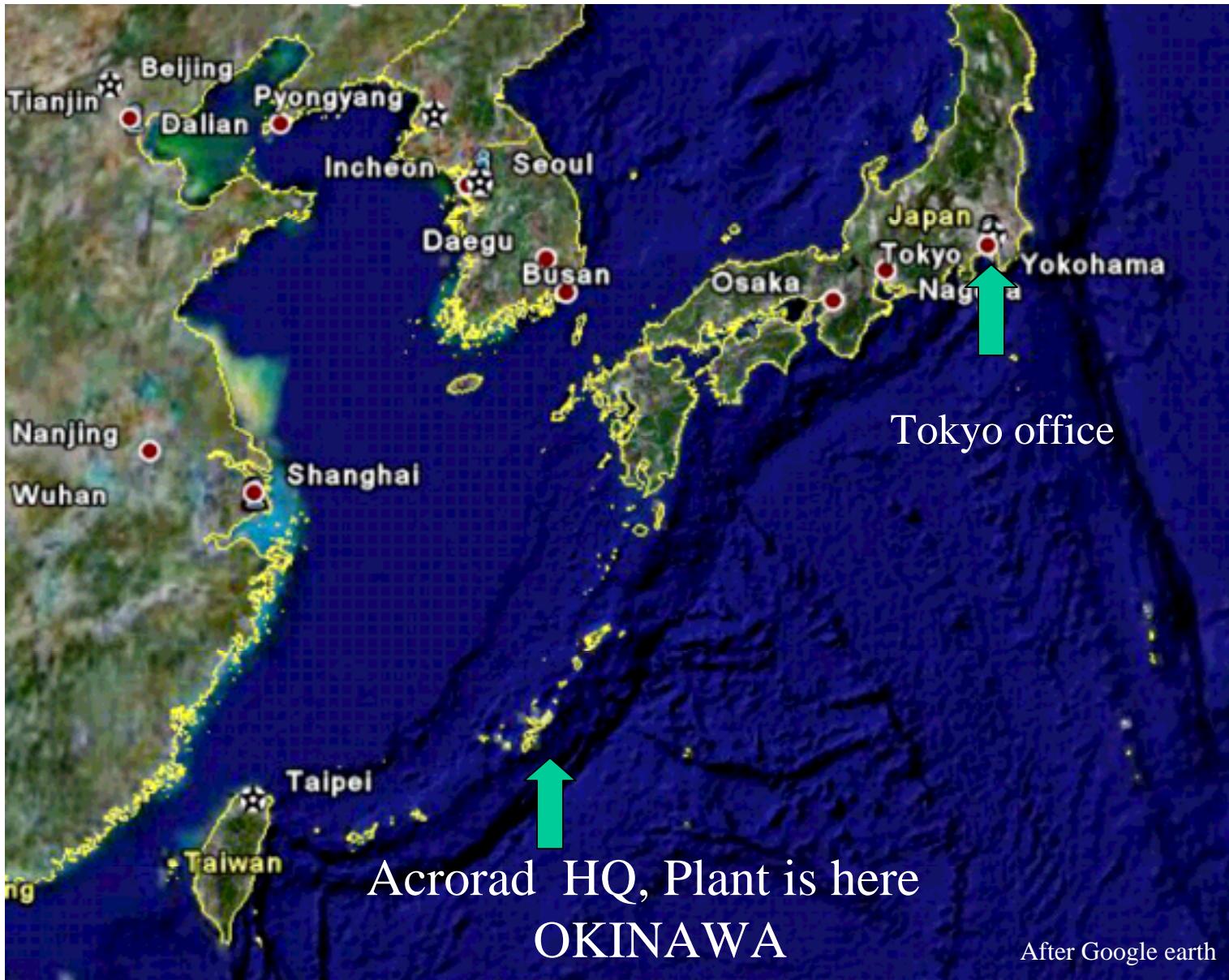
Activities at Acrorad

February 2007



Outline

- (1) About Acrorad
- (2) High purity materials
- (3) CdTe single crystal growth by THM
- (4) Detector characteristics
 - Ohmic detector and Schottky detector
- (5) Detectors for high energy application
 - S³ type and Large area plane type
- (6) Imaging detectors / devices
 - Mini-gamma camera and X-ray imaging hybrid



ACRORAD

Okinawa is a popular “resort “ island,



but.... we have to work in this environment.



Photos by courtesy of Okinawa Convention & Visitors Bureau



Okinawa plant



Capital : 10M\$

Number of employees : 43

Manufacturing facilities : 15,500ft² (1443m²)



History

- ~1987 : Developed **the high purification process for Te and Cd** (Nippon Mining Co.)
- 1988 : Started R&D of **CdTe detector and CdTe growth by THM (1.2")**
- 1990 : CdTe detector are adopted for bone densitometers
- 1995 : Started **2"** THM growth
- 1999 : Delivered over 30,000 detectors for ESA gamma telescope satellite project
ISGRI/ INTEGRAL
- 2000 : MBO of the CdTe detector business. **Acrorad founded**
Started 3" THM growth
- 2005 : Started R&D of **4"** THM growth
- 2006 : Delivered **700,000 Schottky detectors** for Medical Application in a year



Acrorad

Acrobatic Radiation → Acrorad

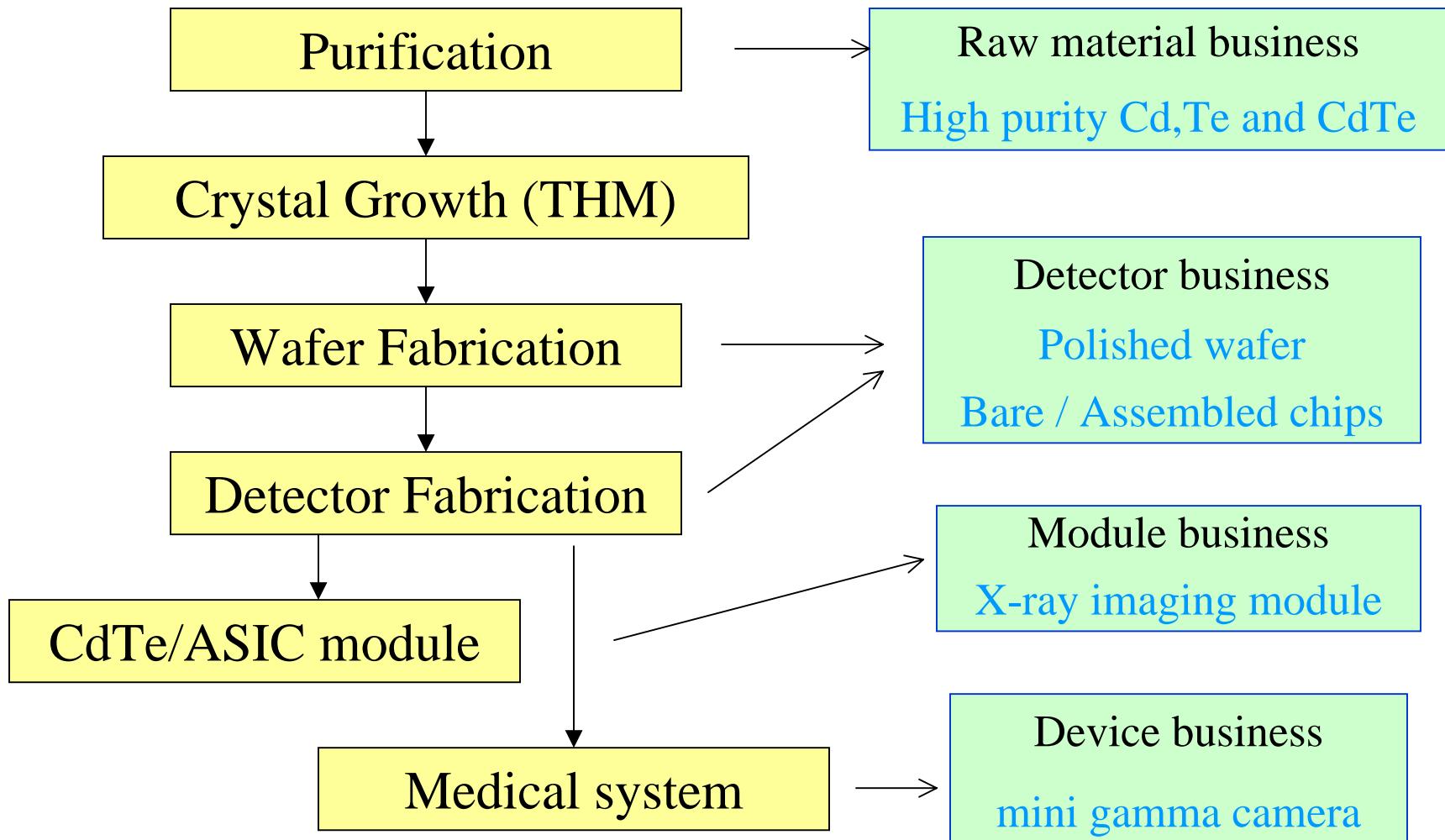


We challenge the new radiation detector technology
with the acrobatic mind (free imagination)



ACRORAD

Production process





Purification of raw materials



High purity metals in Acrorad

We purify the raw materials in house,

- (1) to reduce the production cost, which is the key for CdTe to be used in many application fields
- (2) to improve the CdTe detector qualities, as the purity is the most important for the radiation detector
- (3) to secure the material supply



CdTe single crystal growth by THM

Requirements of the CdTe crystal for radiation detector

(1) Large μ products & high resistivity

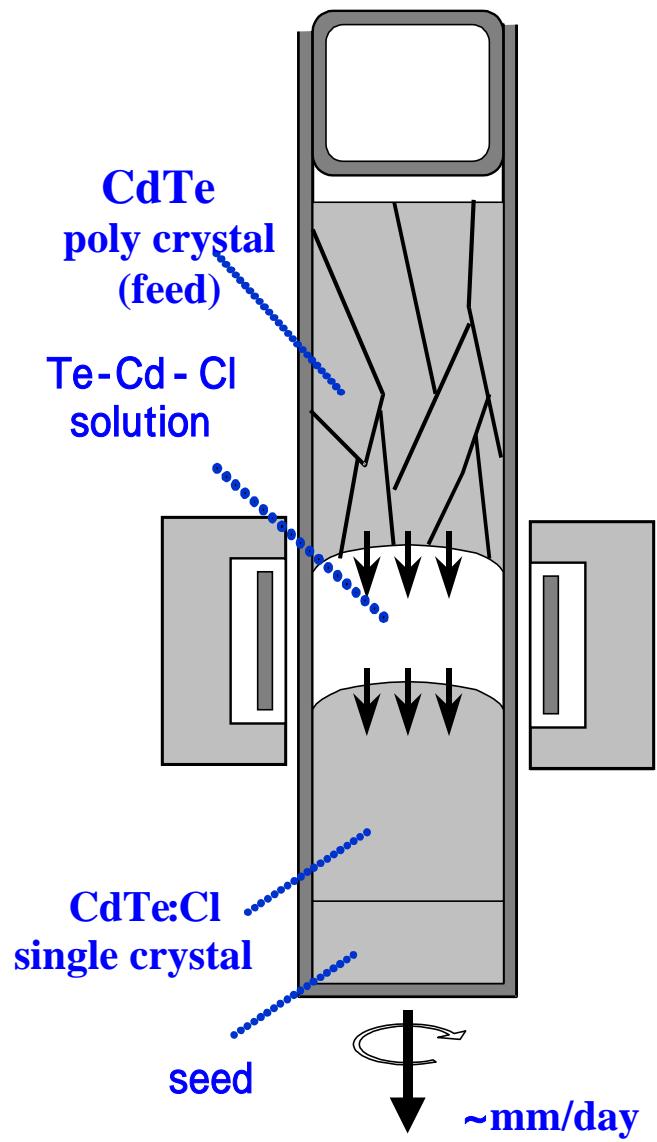
high purity Low temperature growth

Impurity gettering effects of the molten zone

(2) Homogeneity Segregation of Cl

(3) Productivity Large diameter



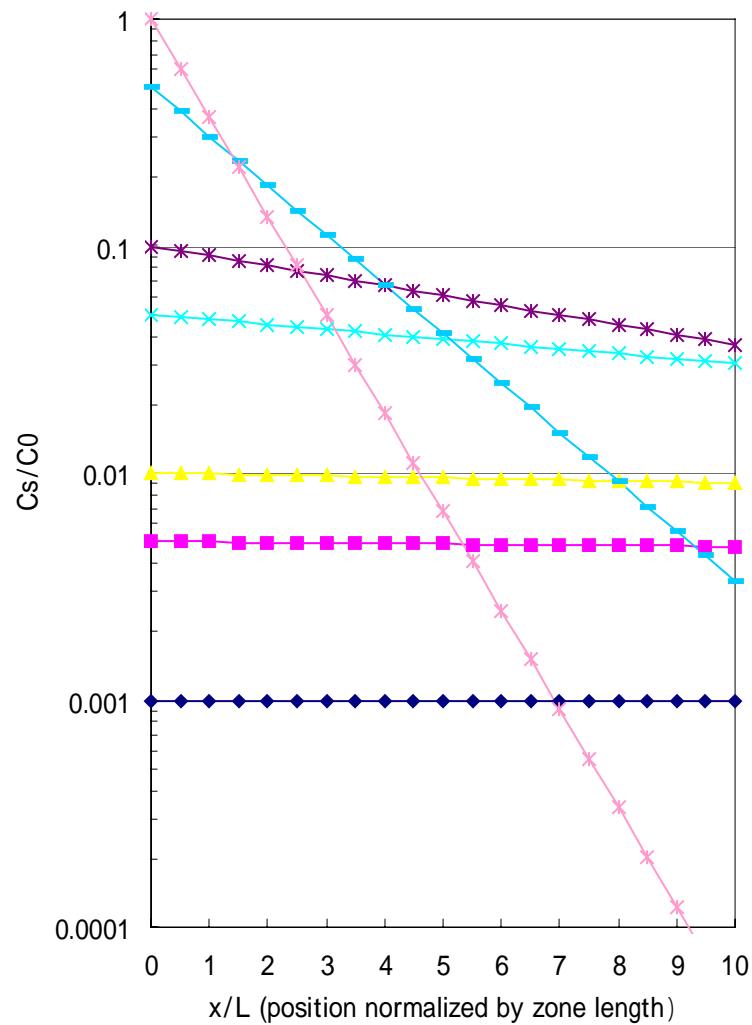


Crystal growth of CdTe:Cl by THM

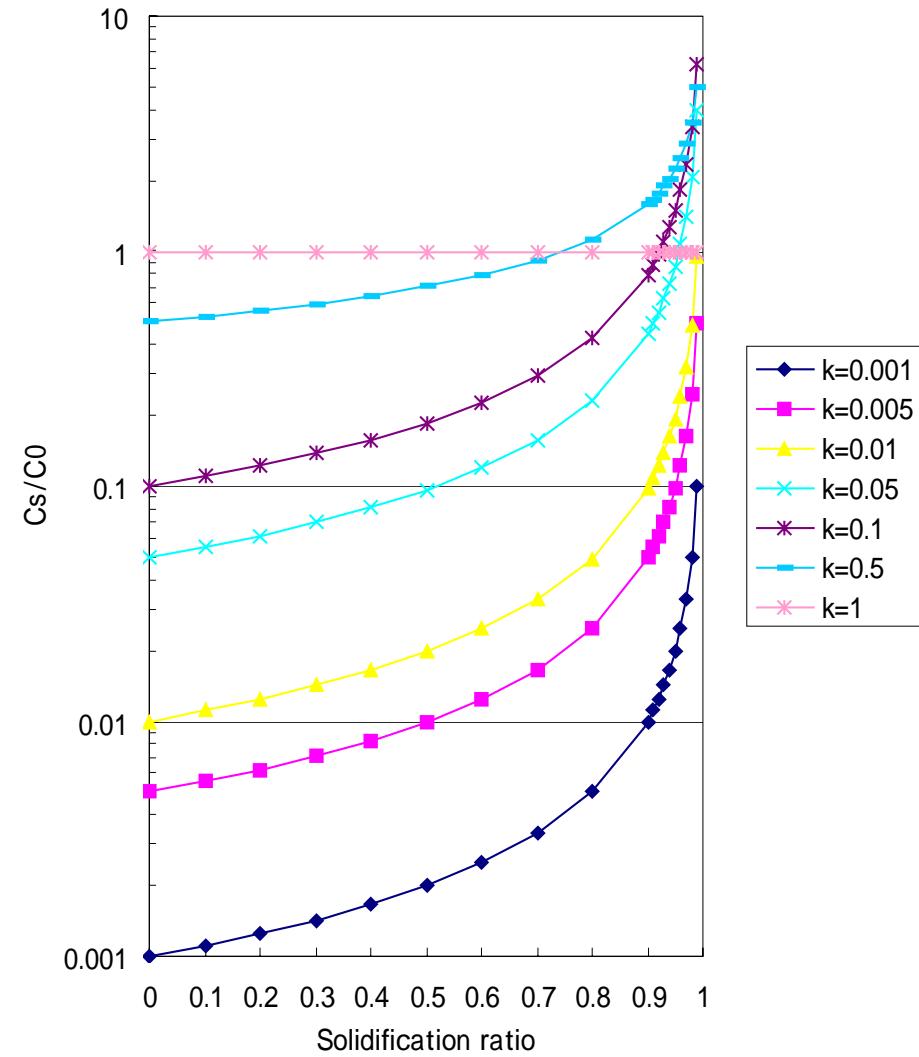


ACRORAD

Distribution of dopant concentration

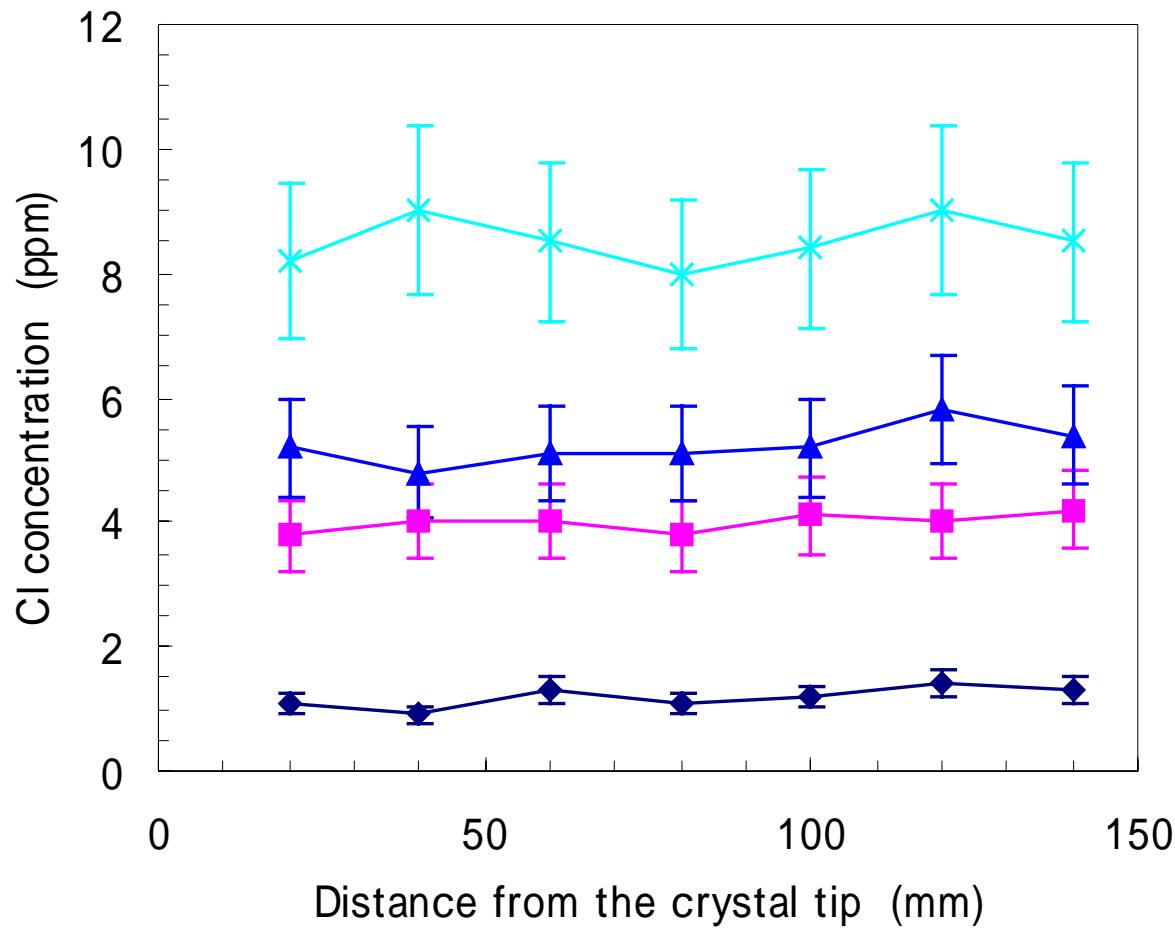


(a) THM



(a) Bridgman method

Distribution of Cl in THM crystal



Evolution of CdTe THM growth in ACRORAD



1.26 inch
1988~1998

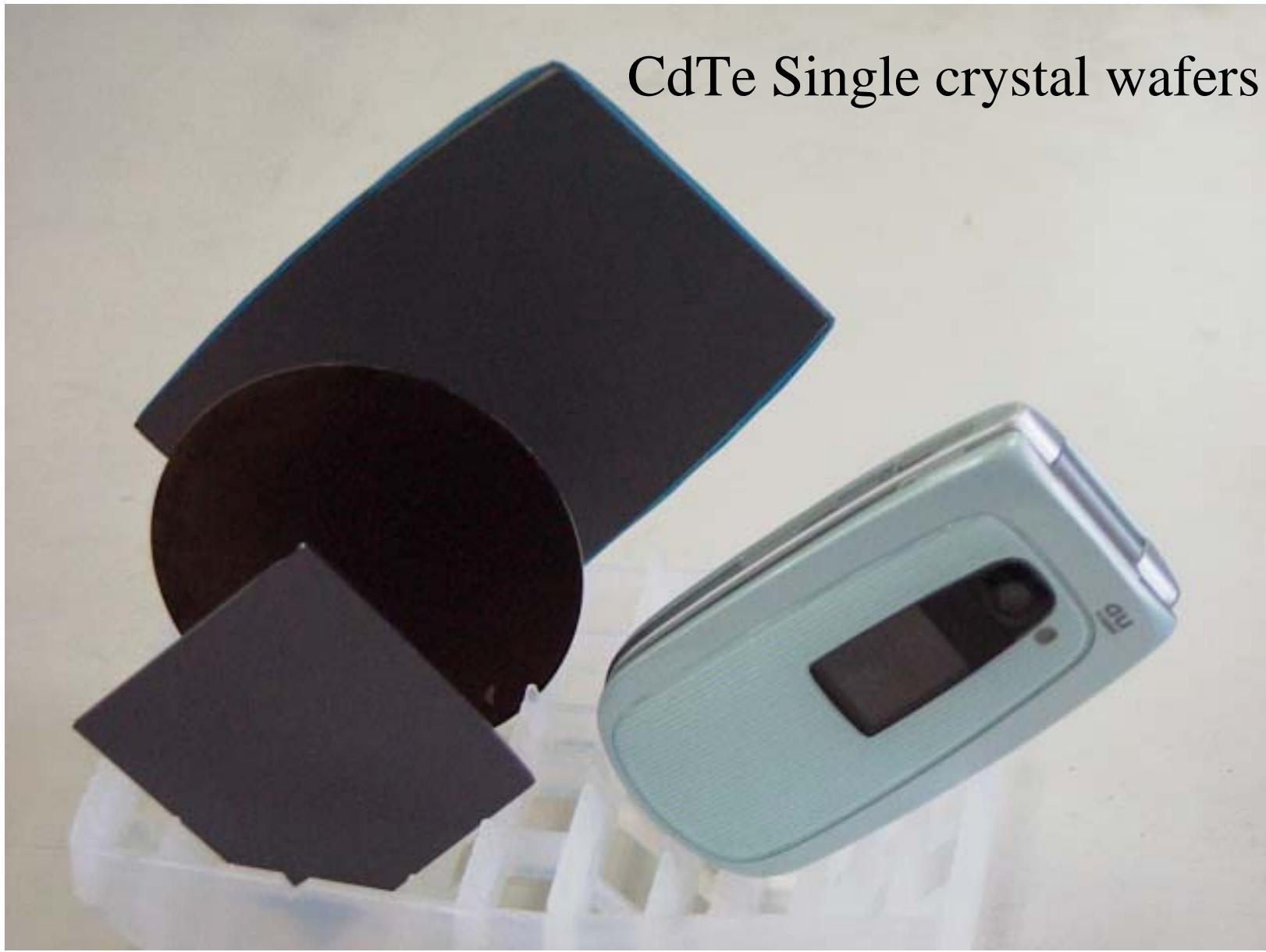
2 inch
1995~2002

3 inch
2000~



ACRORAD

CdTe Single crystal wafers

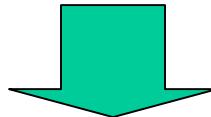


ACRORAD

CdTe single crystal of 3inch diameter

- (1) Uniform performance
- (2) High reproducibility
- (3) Average volume ratio of the largest grain in a ingot (single crystal yield in a ingot) ;

85% over

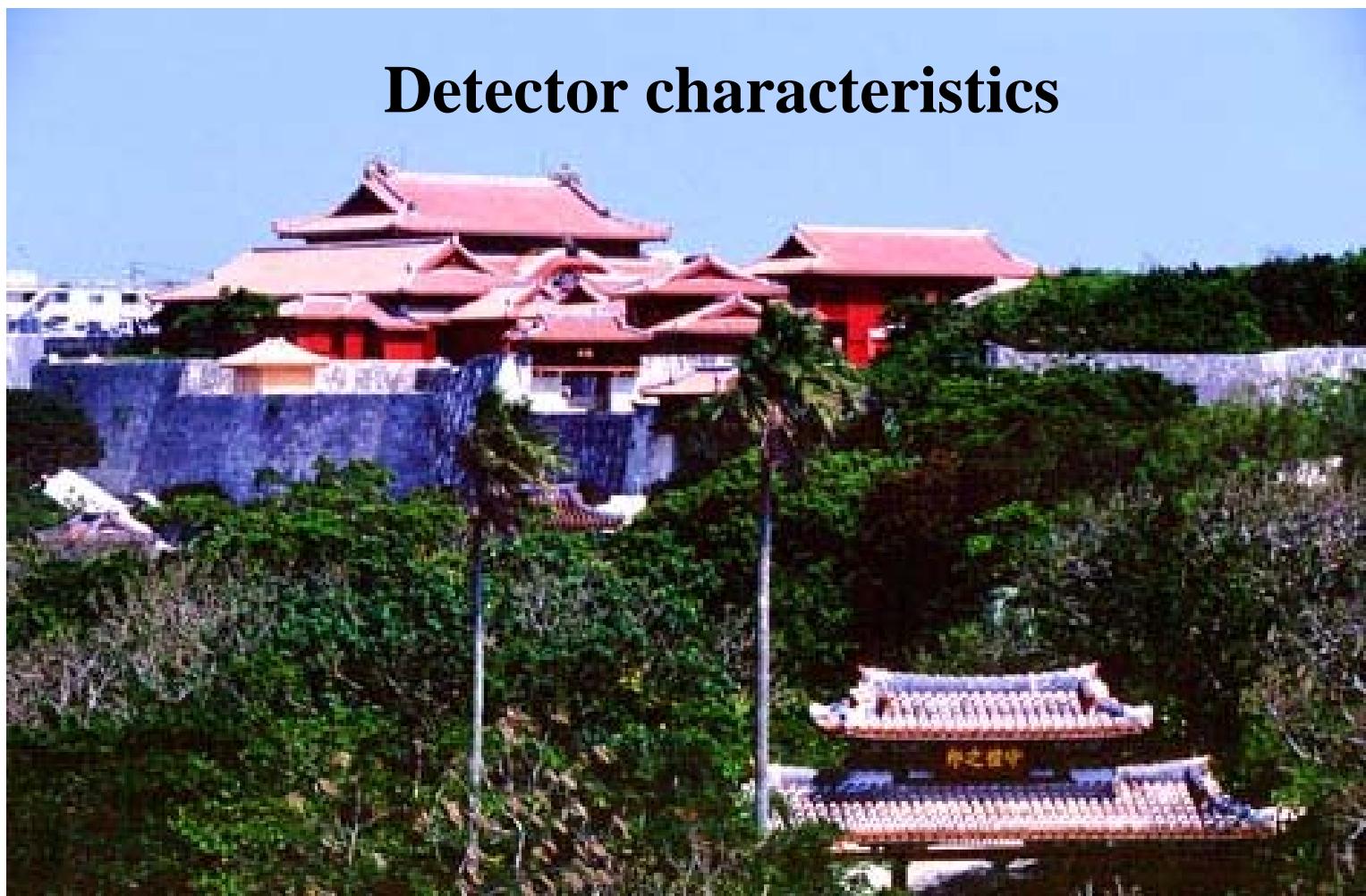


Mass production of CdTe detectors 700kpcs/year

Regular production of single crystal detector of
25x25mm² size for X-ray imager



Detector characteristics



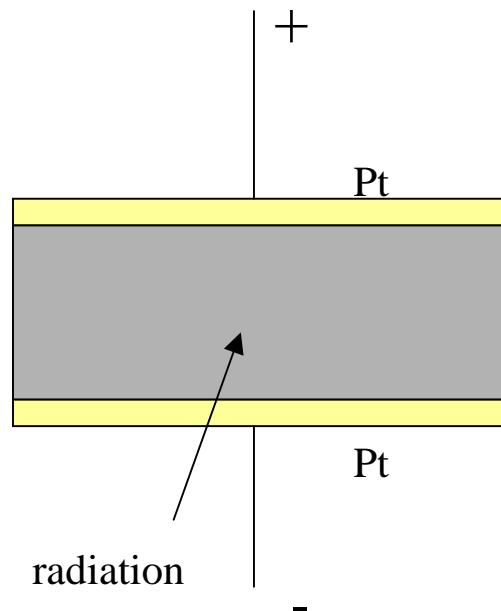
Shuri Castle (G8 summit banquet was held in 2000)

Photos by courtesy of Okinawa Convention & Visitors Bureau



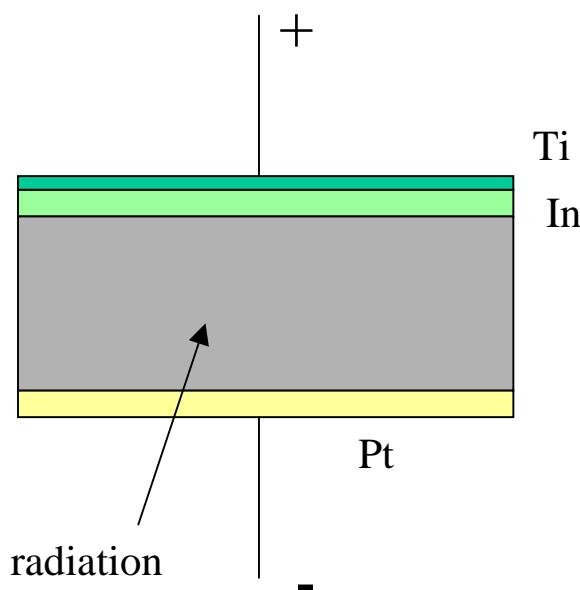
Acrorad CdTe detectors

(1) Ohmic type



No polarization

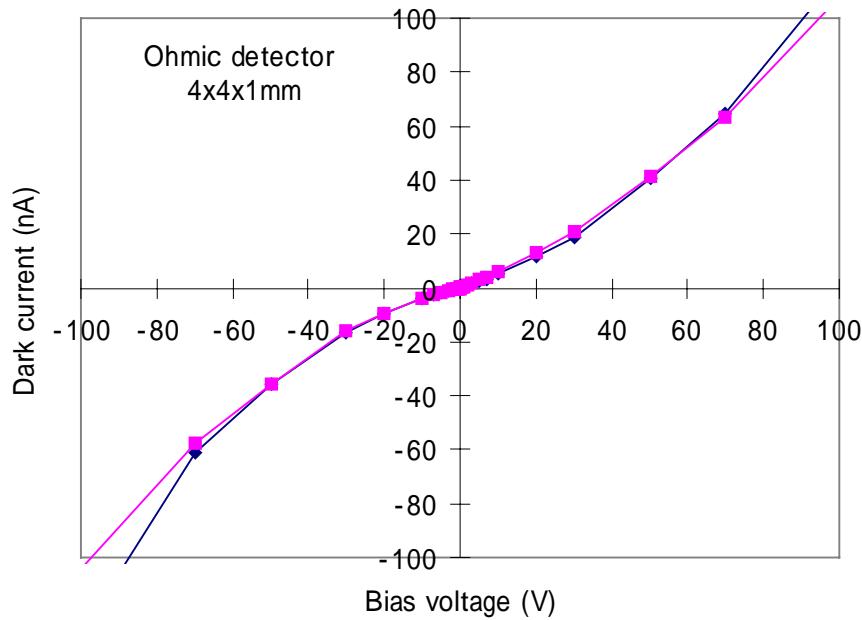
(2) Schottky type



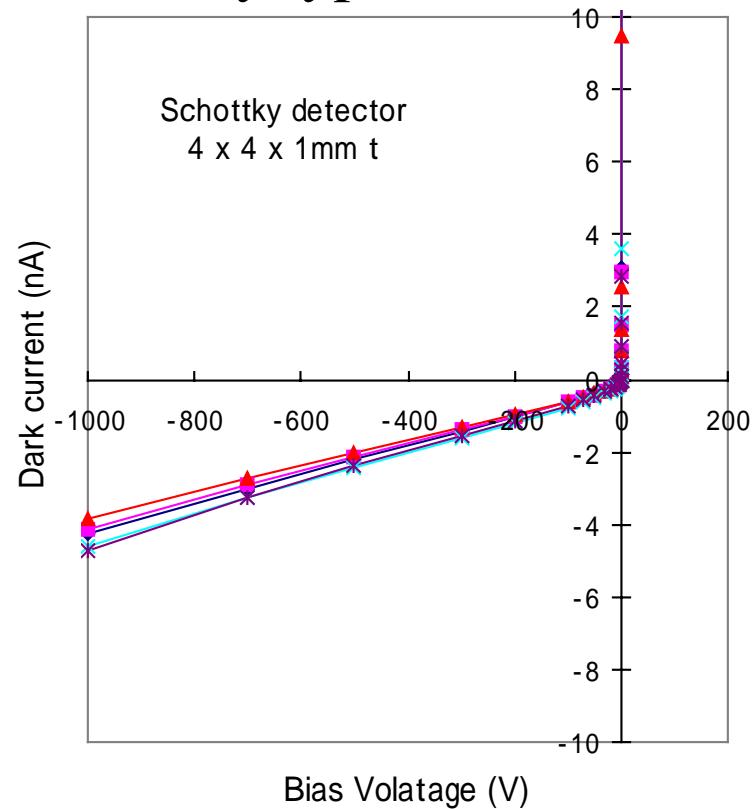
High bias voltage
Low dark current

I-V characteristics

(1) Ohmic type



(2) Schottky type



Detector resistivity

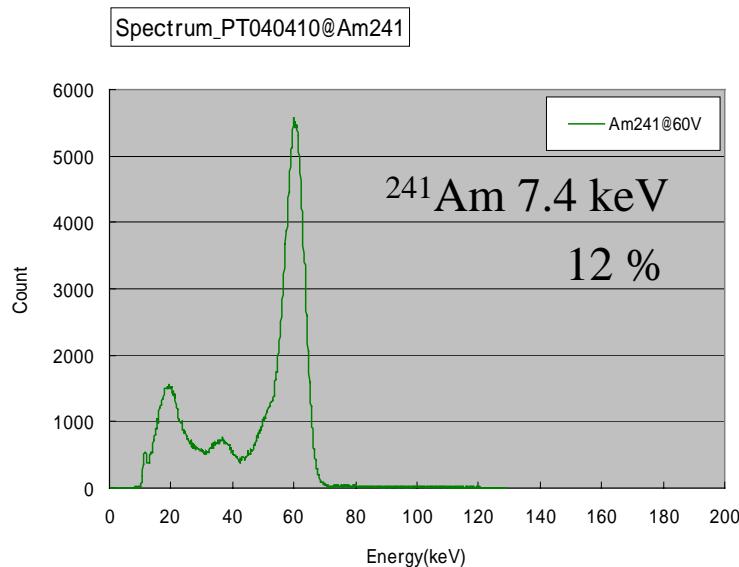
1.8×10^9 cm @70V

dark current ~ 70nA

Detector resistivity

3.7×10^{11} cm @700V

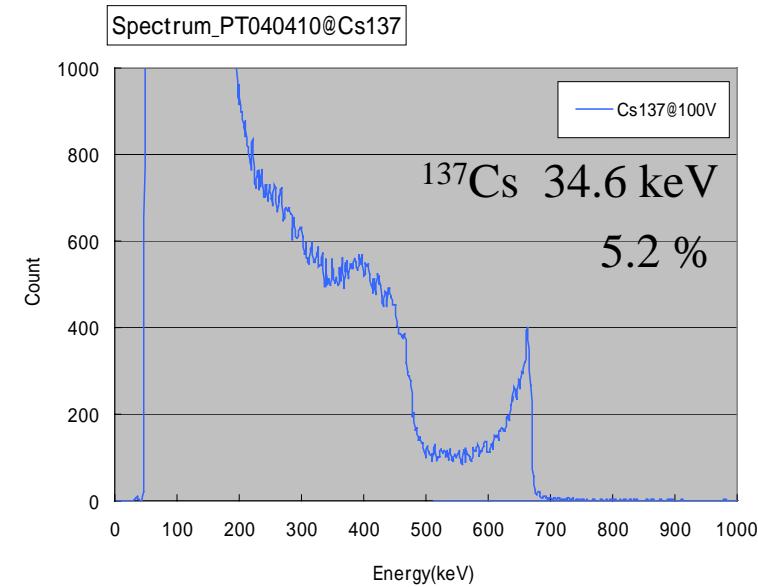
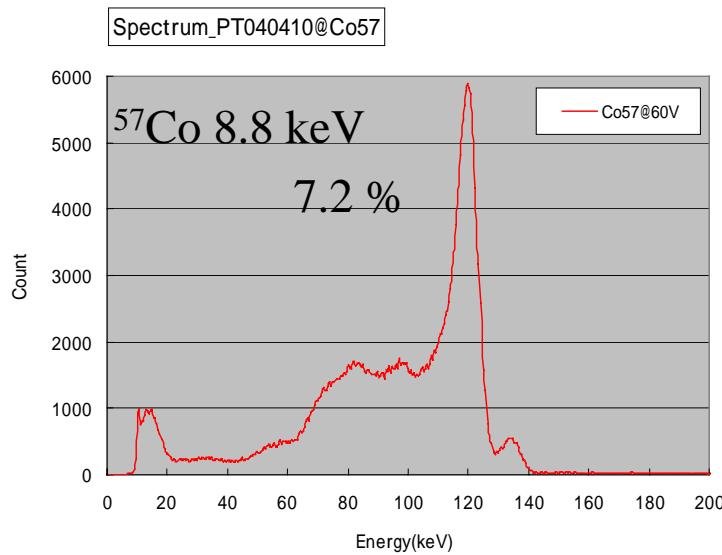
dark current ~3nA

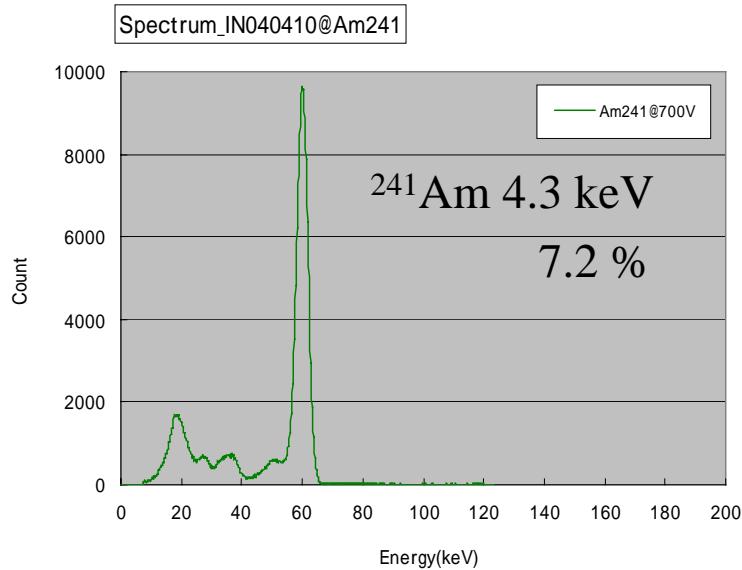


Energy spectrum

Ohmic detector

4x4x1 mm

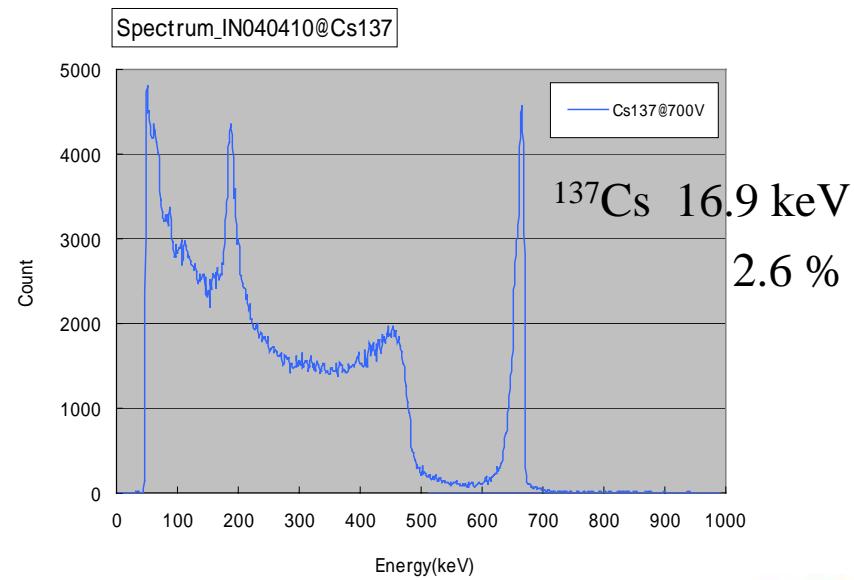
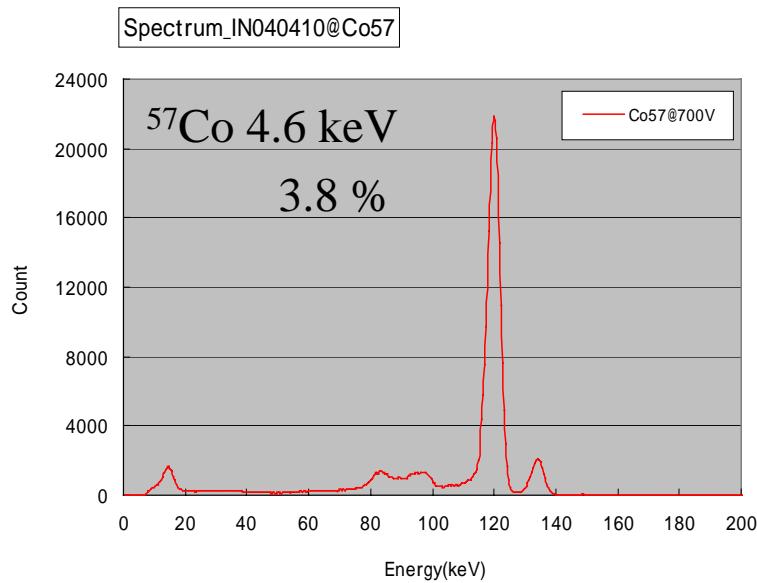




Energy spectrum

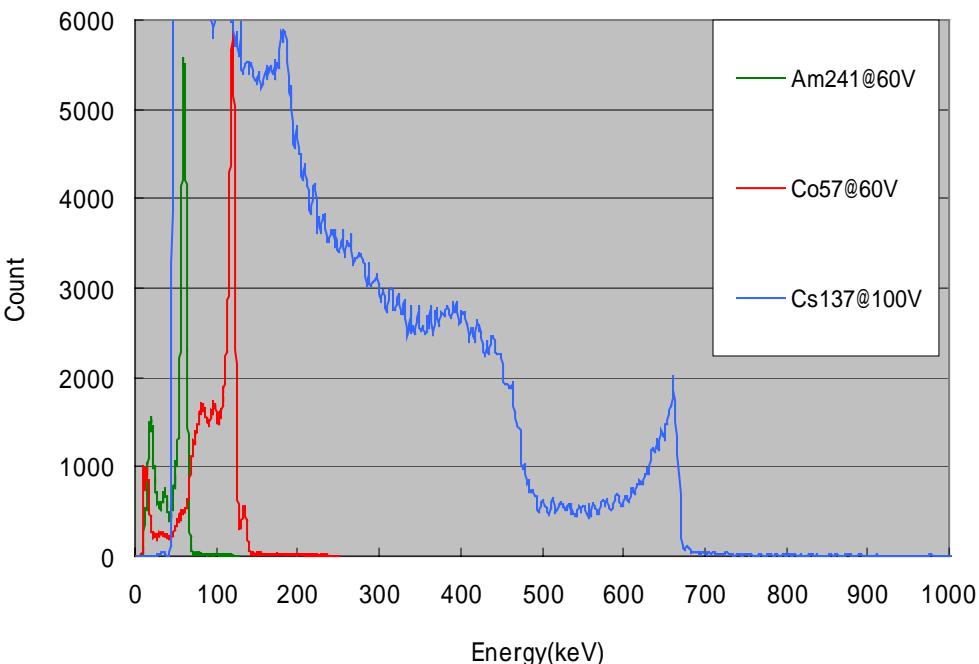
Schottky detector

4x4x1 mm

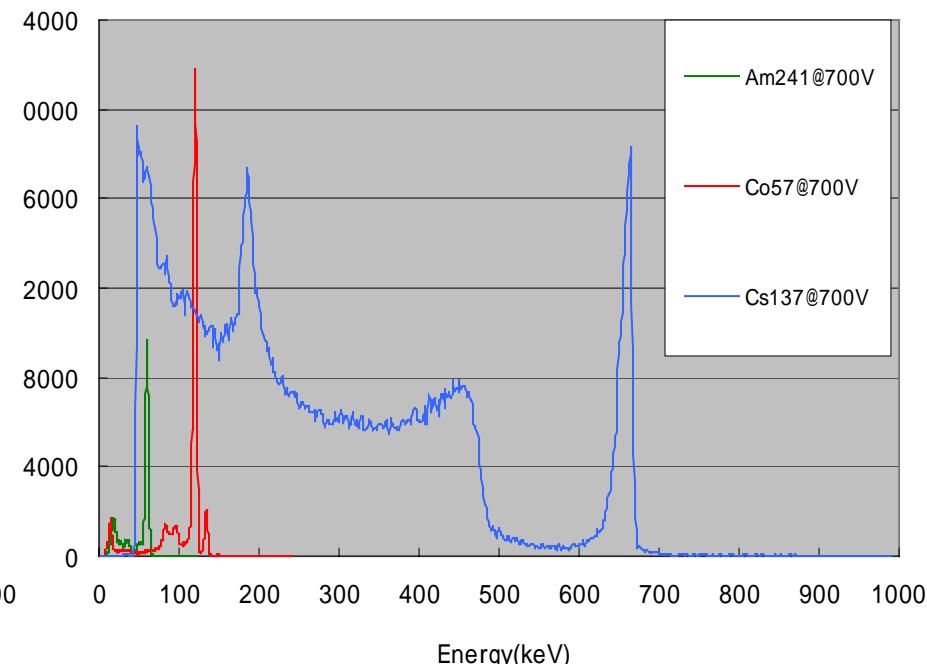


Energy spectrum comparison size 4x4x1mm

Ohmic



Schottky

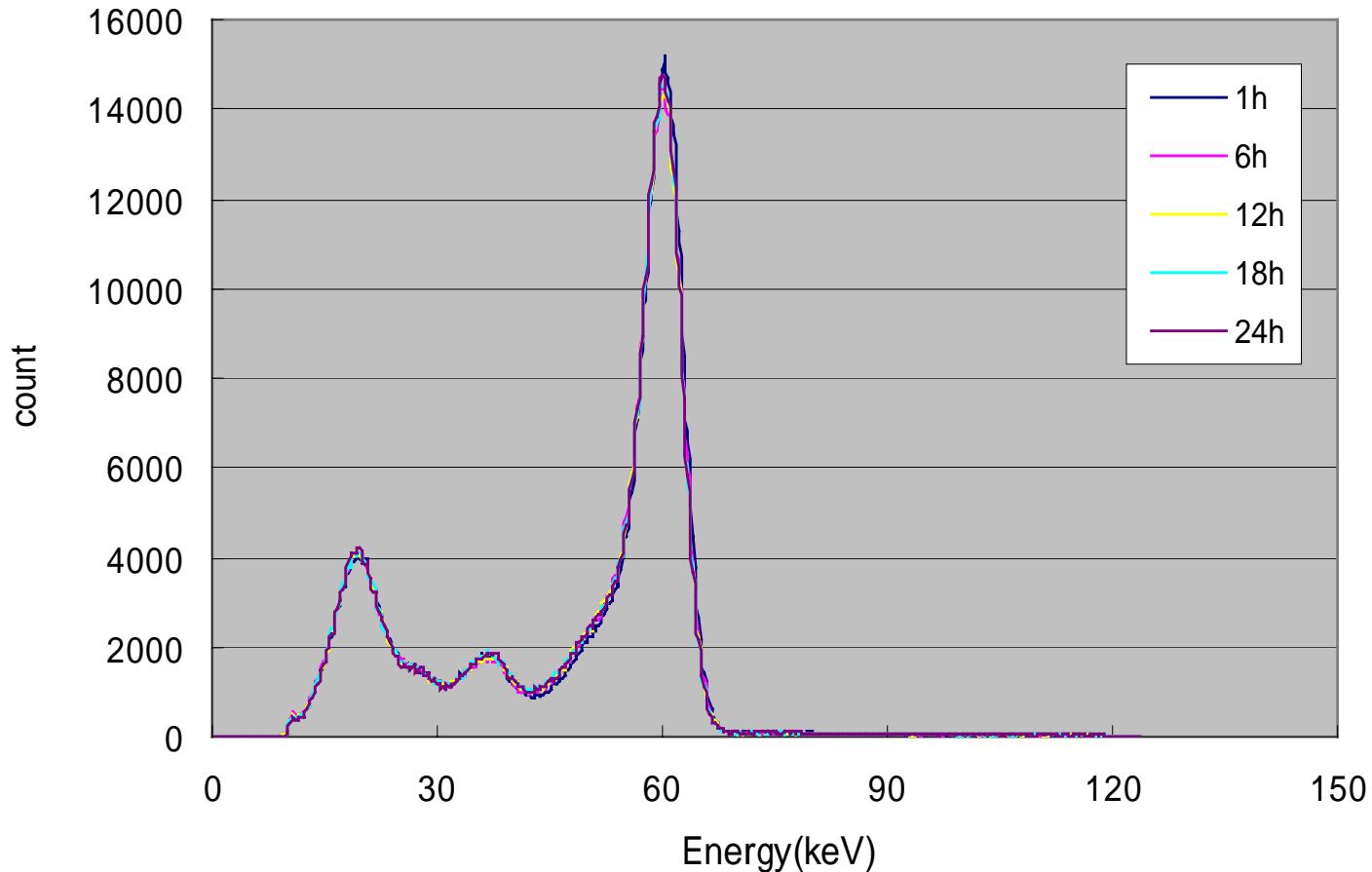


	Ohmic		Schottky	
	keV	%	keV	%
241Am	7.4	12.4%	4.3	7.2%
57Co	8.8	7.2%	4.6	3.8%
137Cs	34.6	5.2%	16.9	2.6%



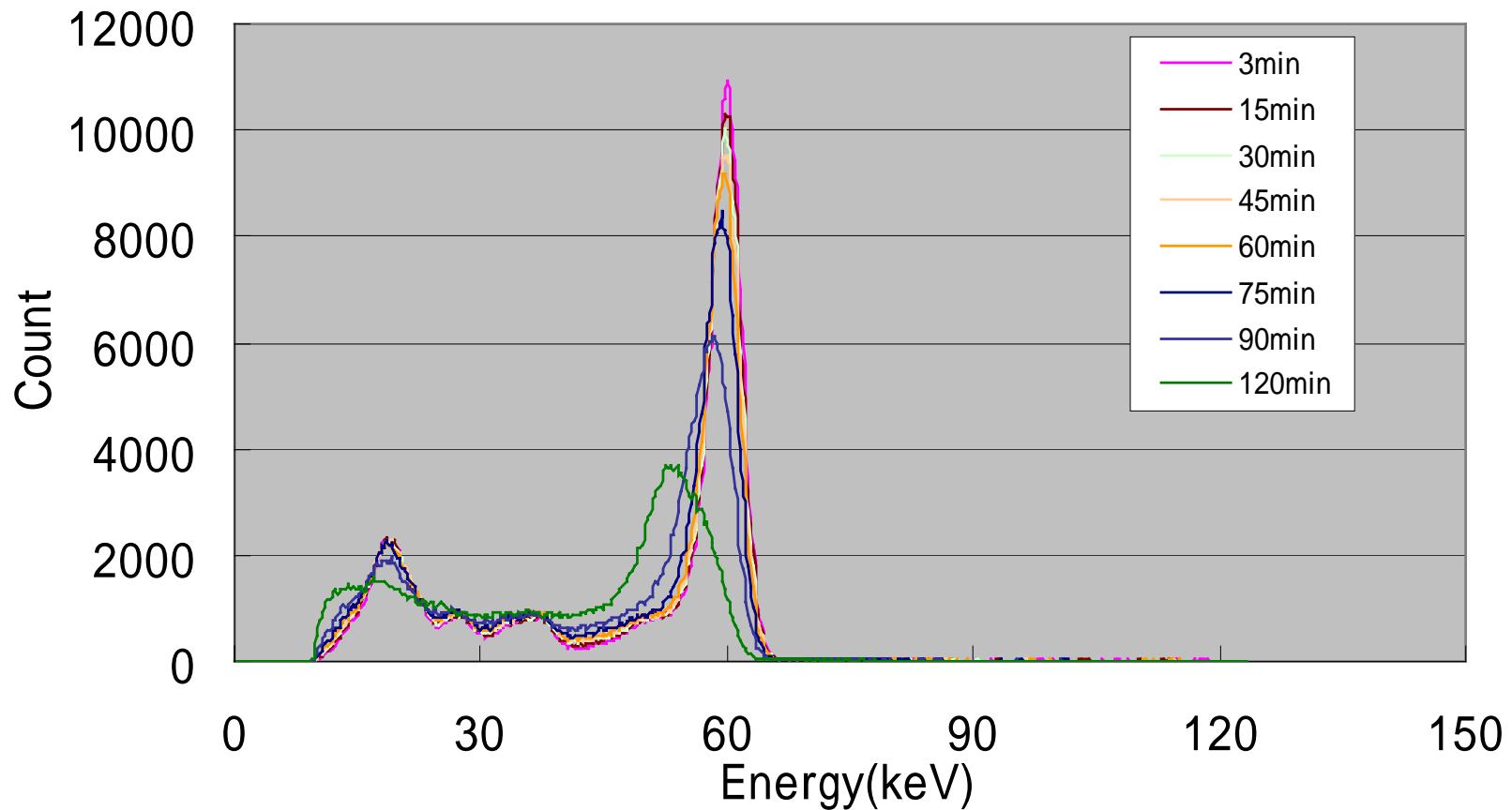
Stable ohmic detector

Ohmic detector shows no polarization



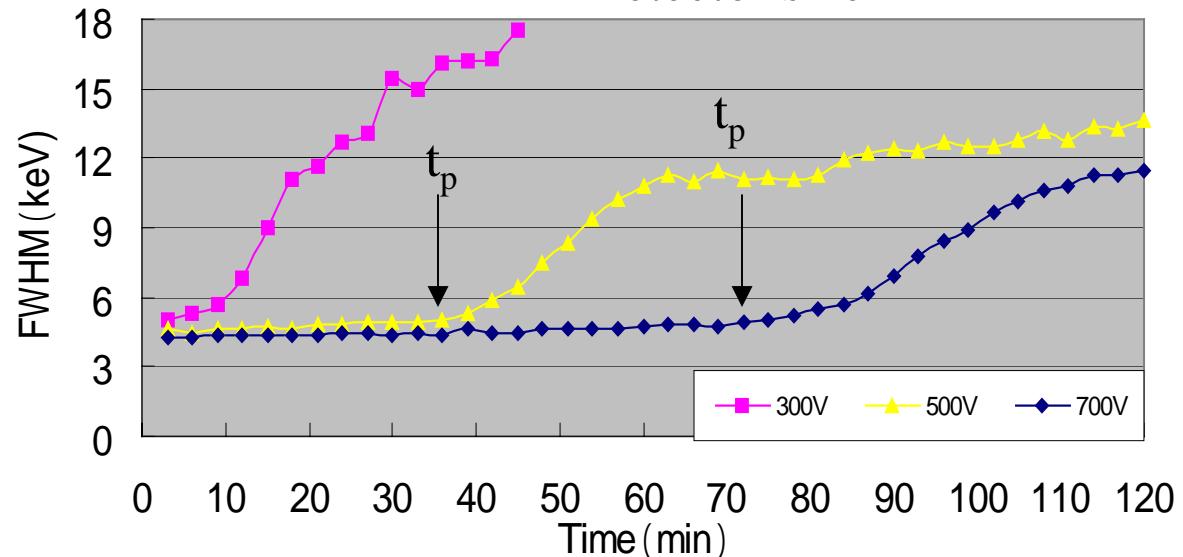
Polarization of Schottky detector

Porarization_Spectrum(IN040410@700V_241Am)

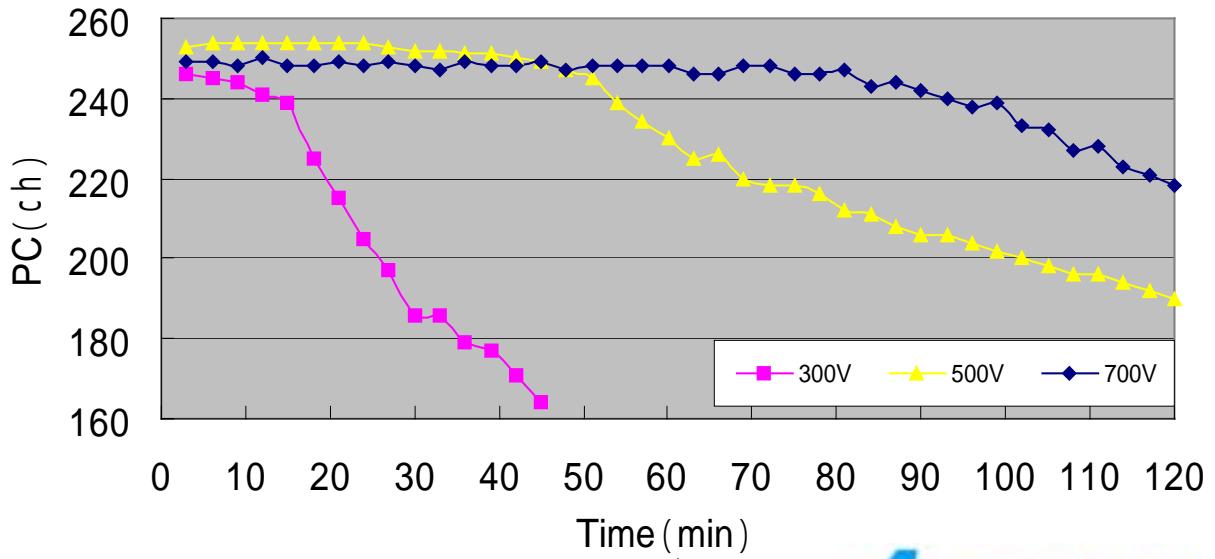


Effect of bias voltage on polarization

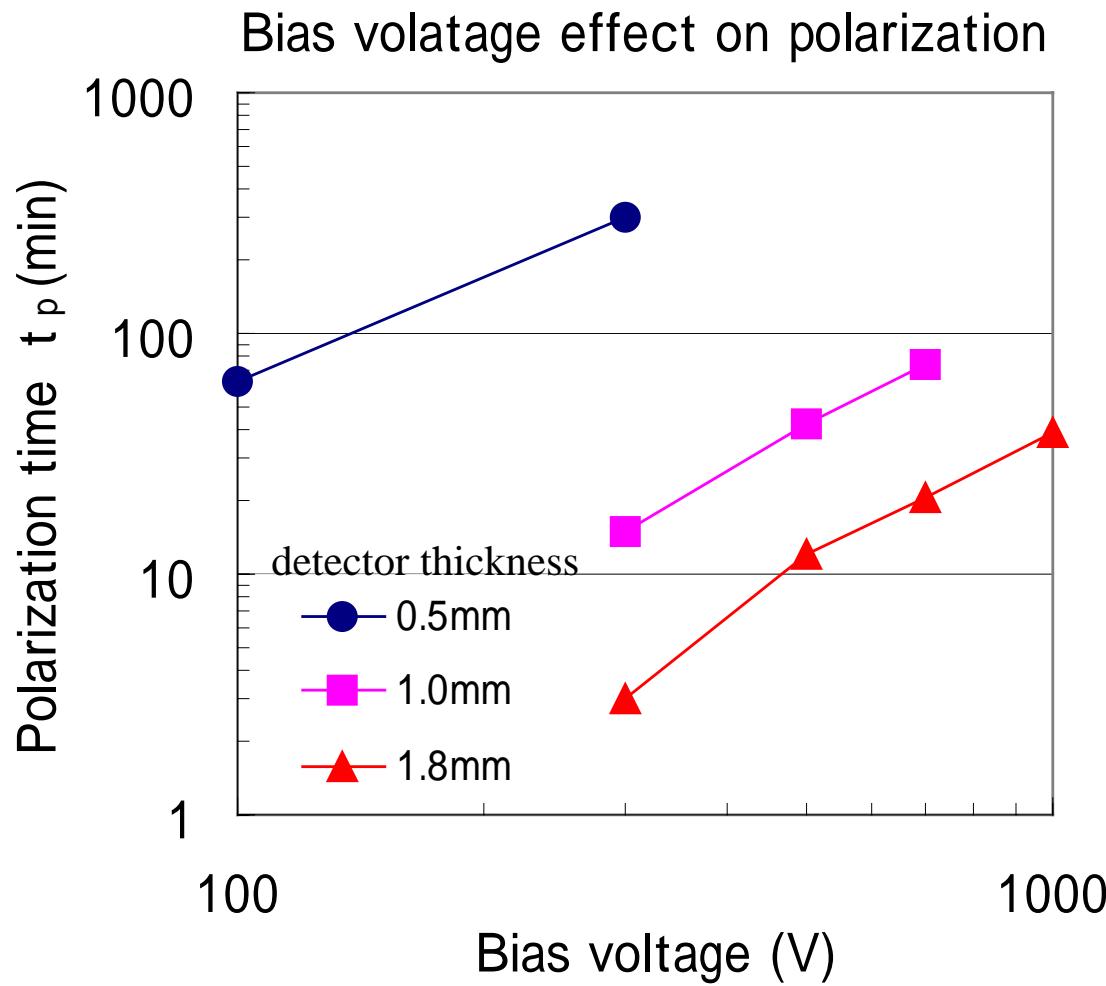
Detector size 4x4x1mm



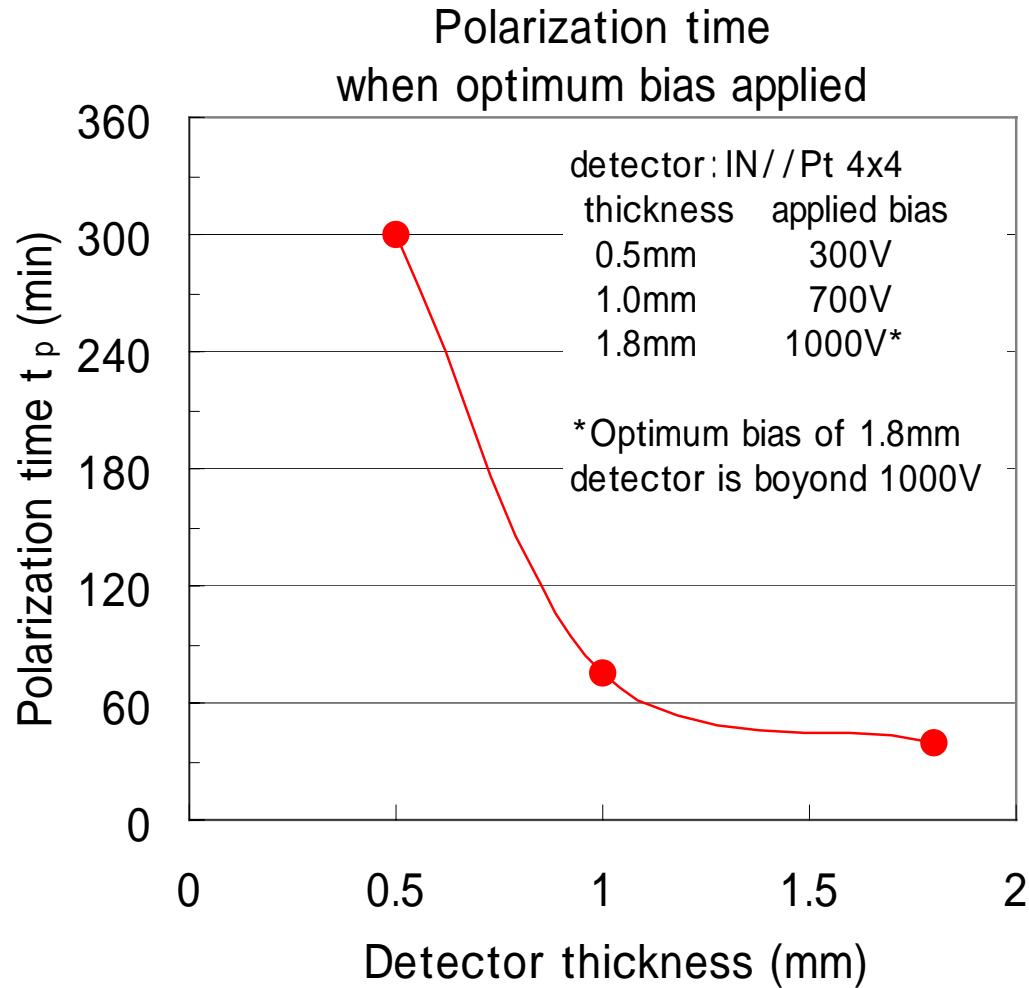
After the bias applied, the spectrum is almost stable until polarization time t_p



Effect of bias voltage and detector thickness on polarization



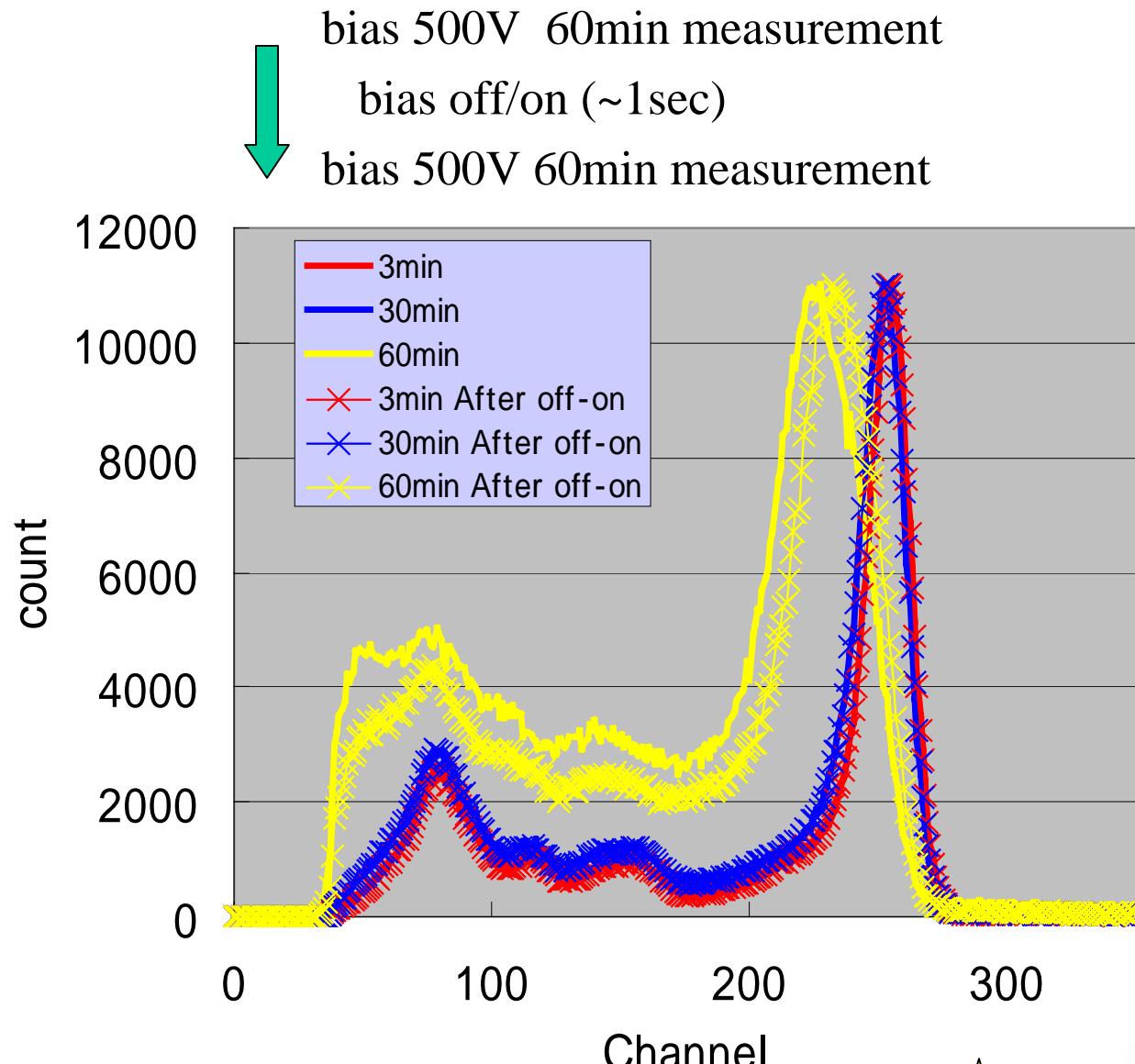
Effect of detector thickness on polarization time



The thinner detector is more stable

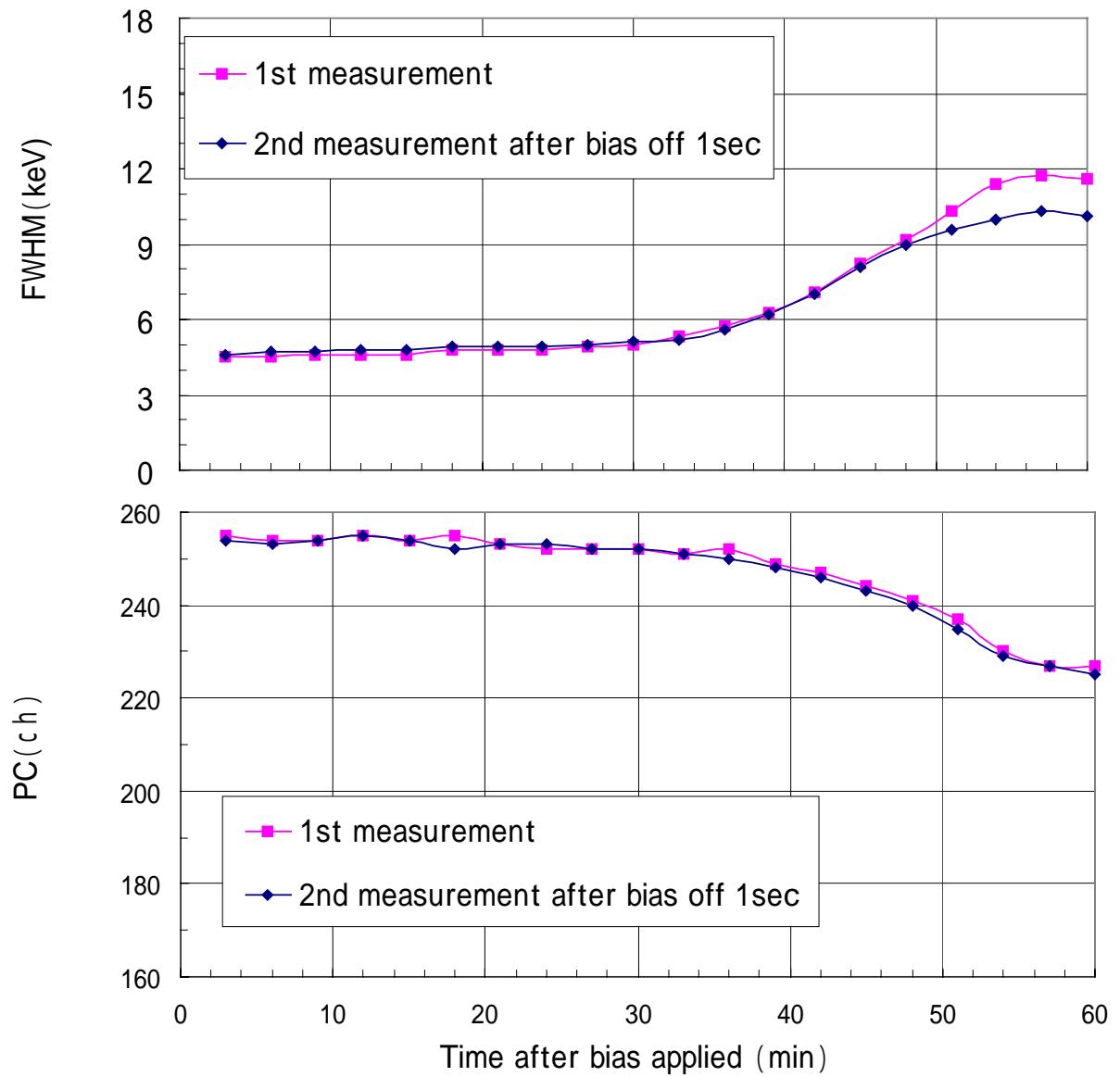


Recovery from the polarization



Recovery from the polarization(2)

4x4x1 bias 500V



Detector characteristics summary

(1) Ohmic detector

low bias voltage 70~100V/mm

moderate energy resolution

stable with time (no polarization)

(2) Schottky detector

high bias voltage 700V/mm

superior energy resolution

polarization

thinner, higher bias voltage

longer polarization time

complete recovery by bias off/on



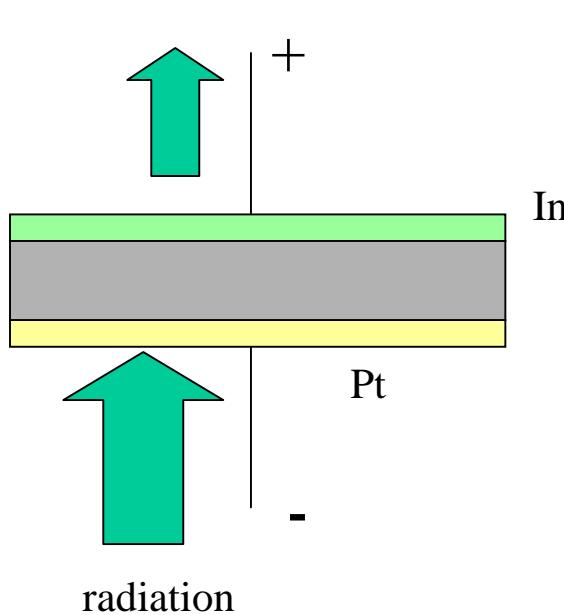
Detector for high energy applications



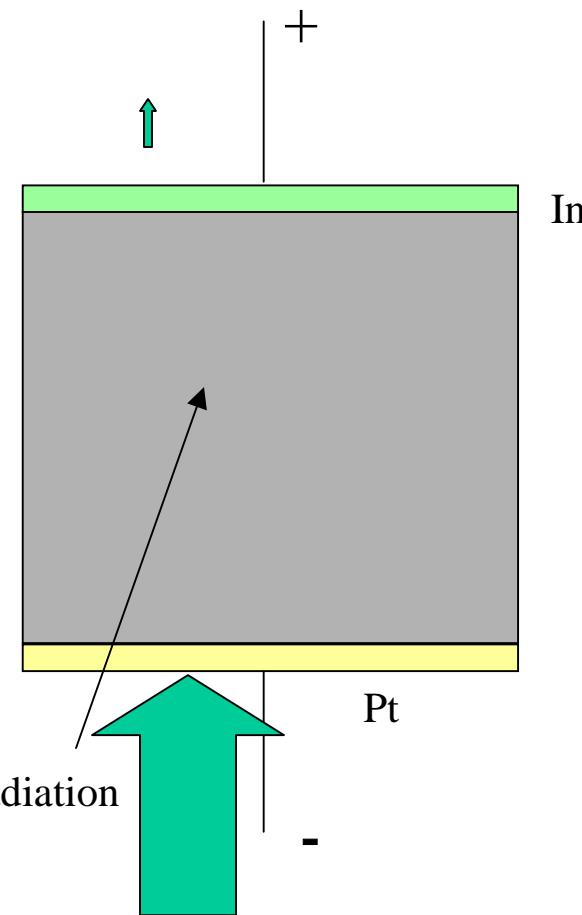
Photos by courtesy of Okinawa Convention & Visitors Bureau



Schottky detector for the higher energy (1)

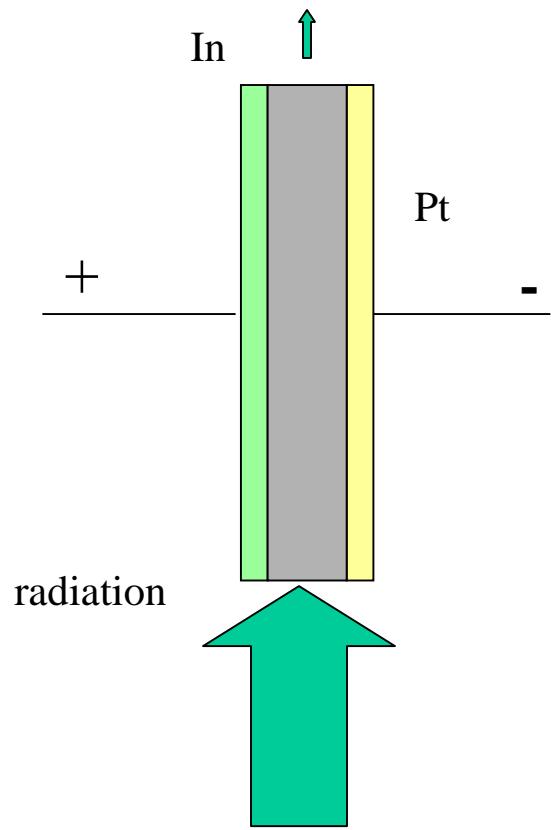


Good resolution and relatively stable but **low sensitivity**



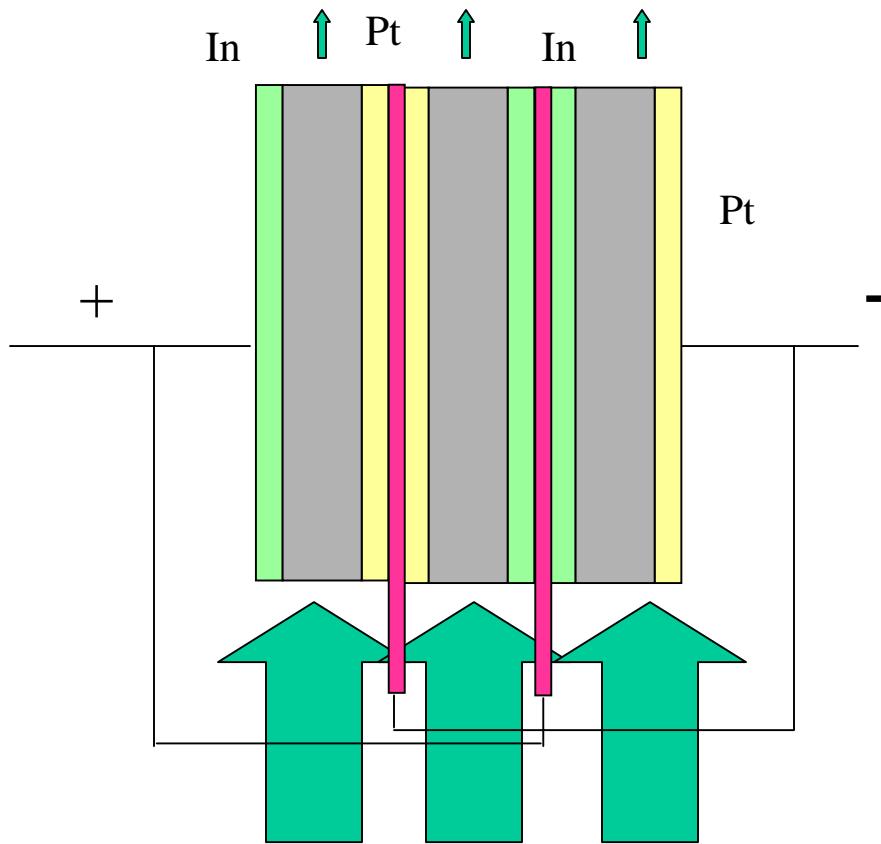
Large stopping power but **severe polarization**

Edge on type



Large stopping power with
good resolution , stability
but small area (volume)

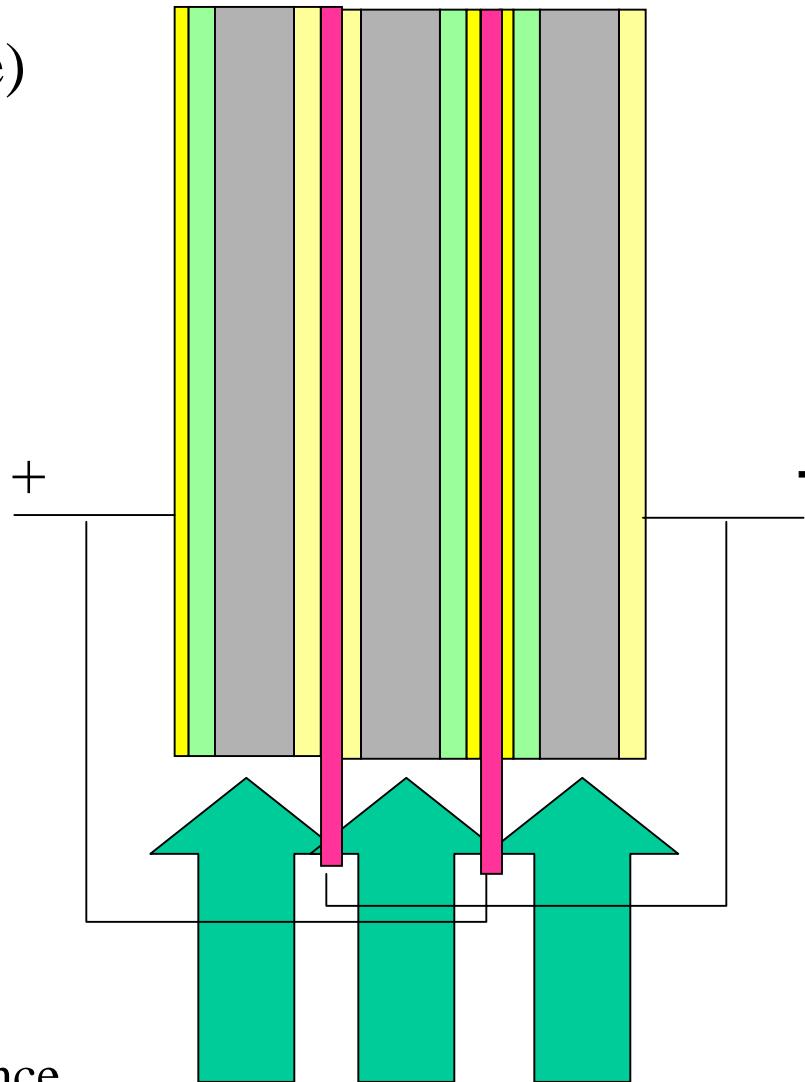
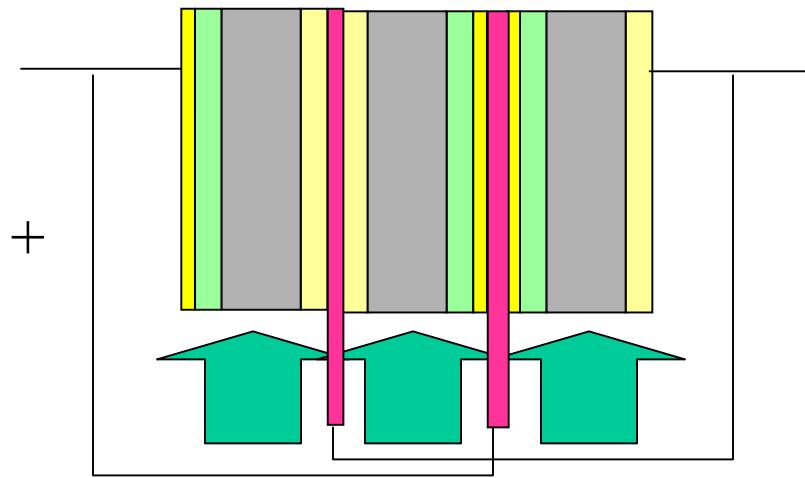
Schottky Stack Structure (S³ type)



Large stopping power with good
resolution , stability , large area



Schottky Stack Structure (S³ type)

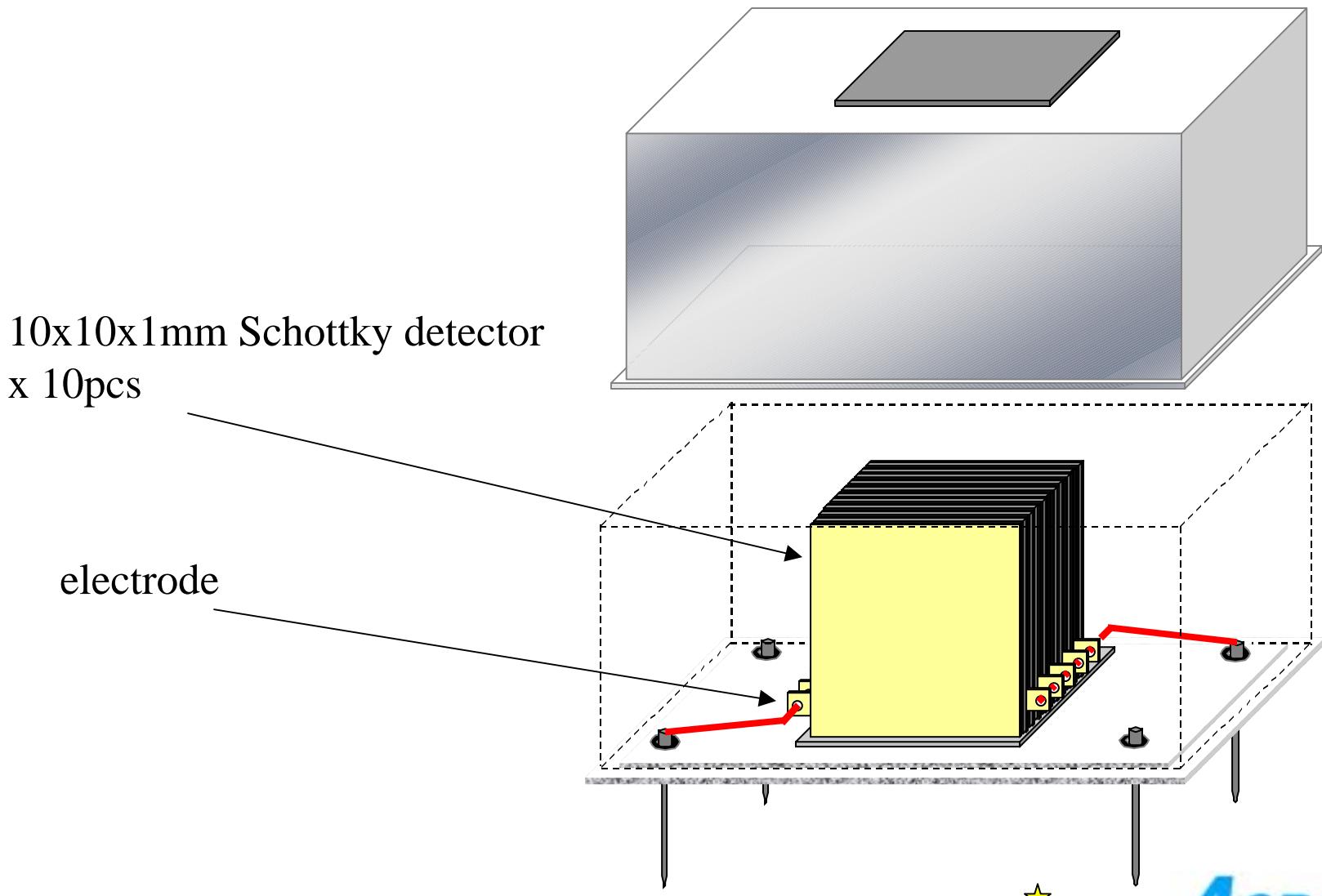


Be able to change the absorption depth
without increasing the carrier travel distance

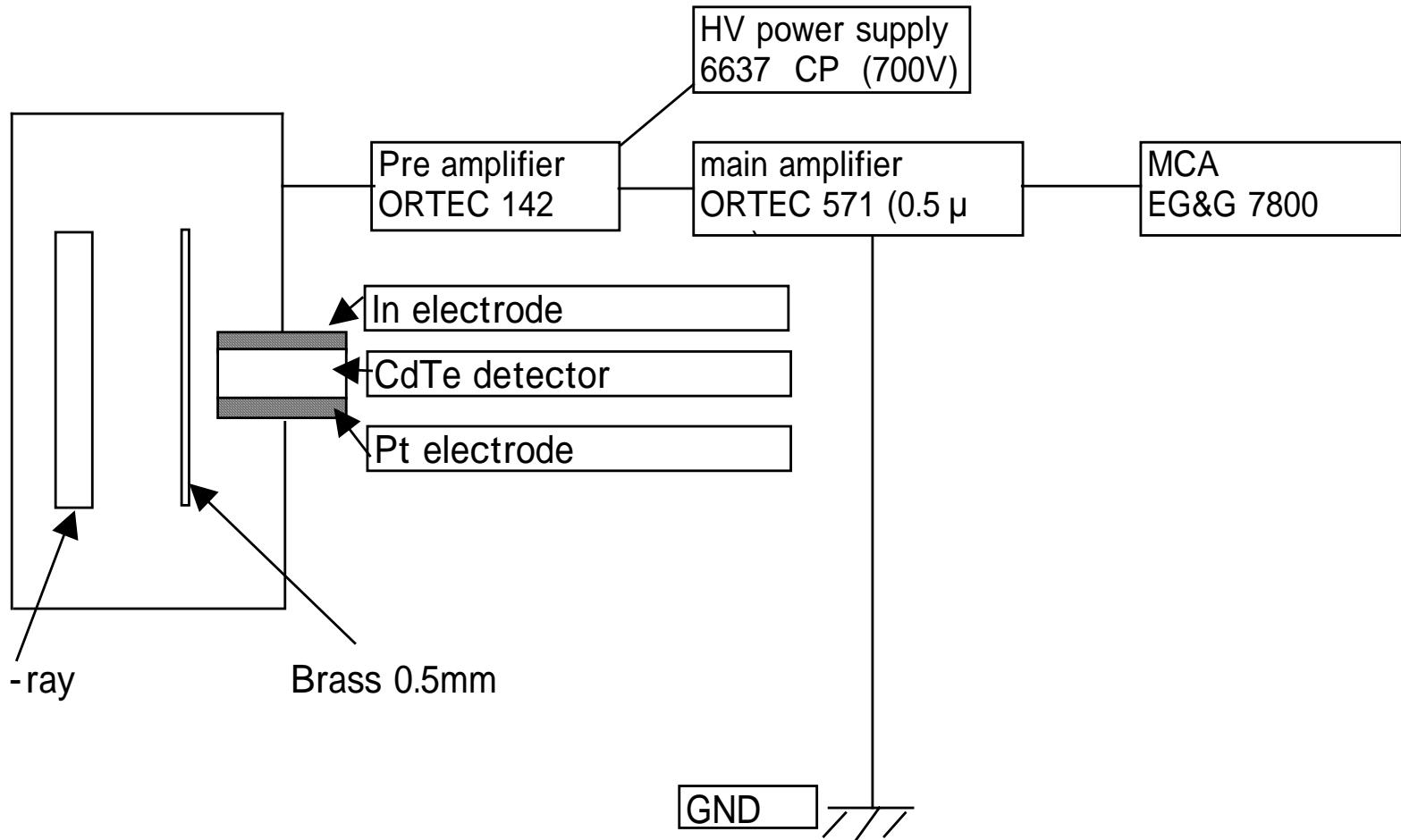
Absorption width 15mm, 20mm,, 50mm,, 100mm possible



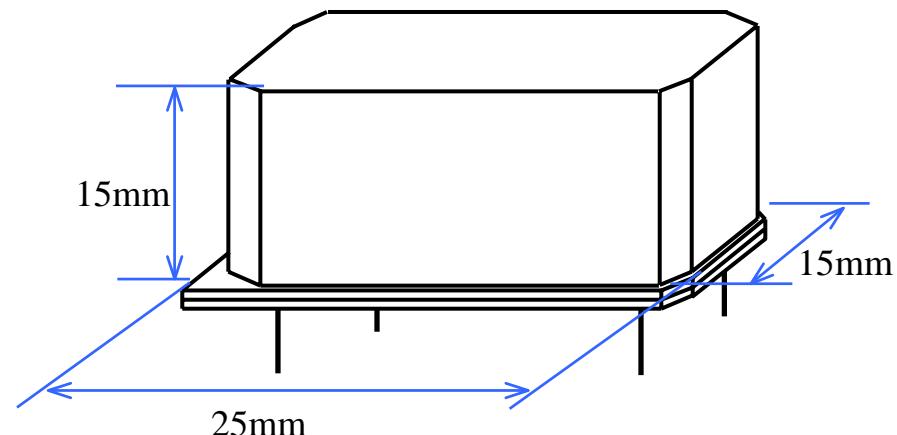
Schottky Stack Structure Detector (S^3 type)



Measurement system



CdTe detector for high energy application (S³-type)



< Specification >

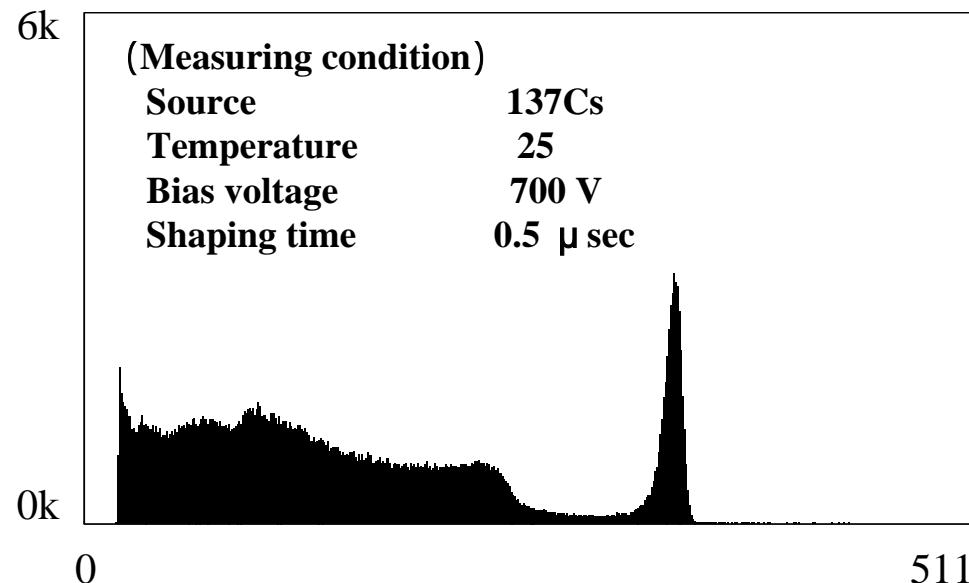
Schottky Stack Structure Detector (S³ type)

Volume : 1,000mm³

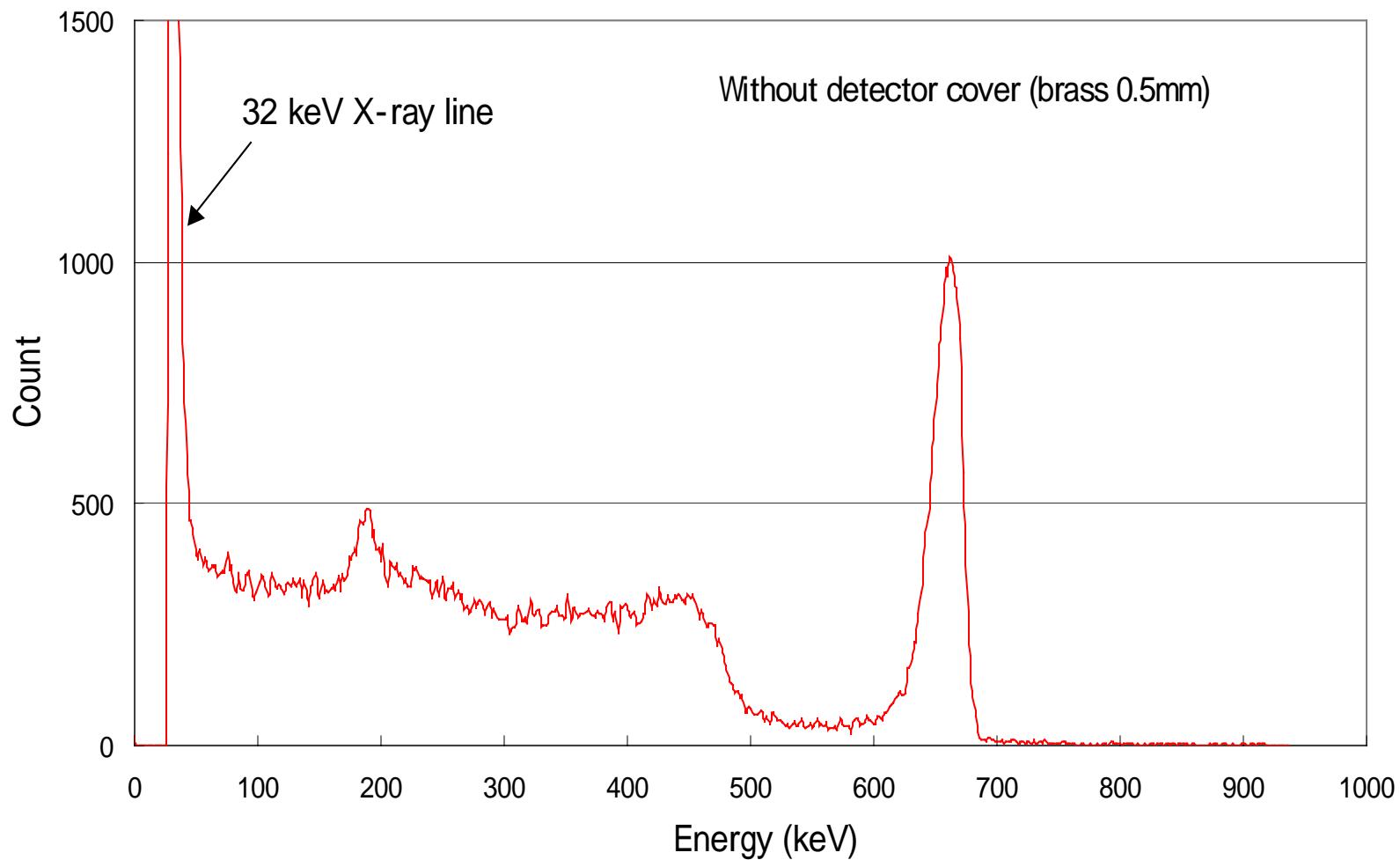
Absorption thickness : 10mm

Bias : 700V

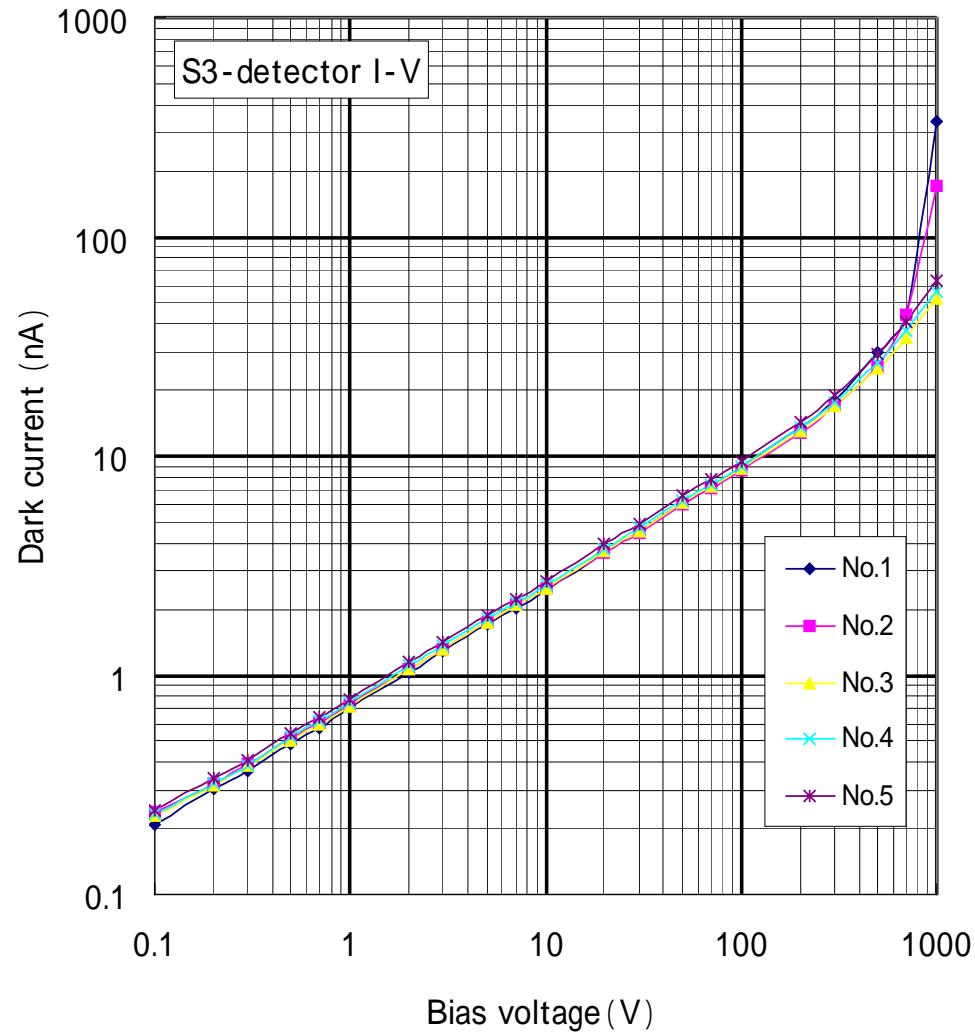
FWHM : less than 4% (700V 25 °C)



S^3 detector spectrum



S^3 detector I-V characteristics



Sensitivity (^{137}Cs)

about 20 cps/ $\mu\text{Sv/h}$

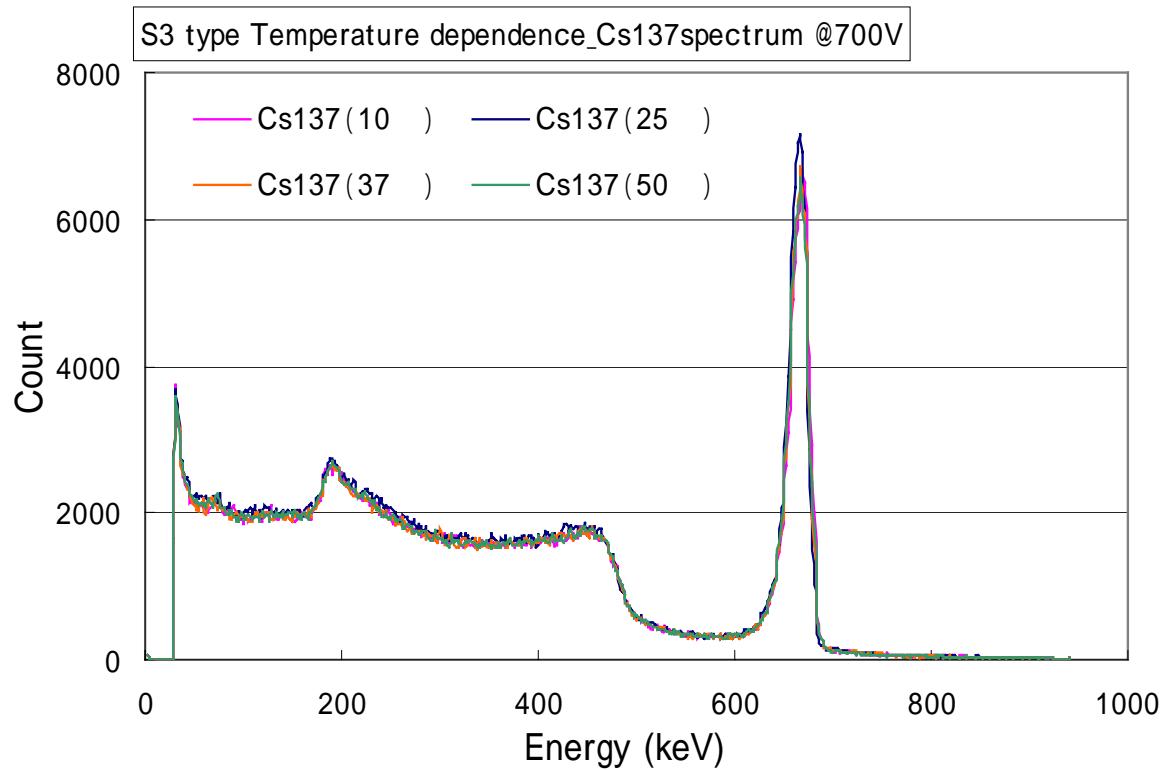
(rough measurement)

Discrimination level 30keV

Lower energy is cut by the brass case

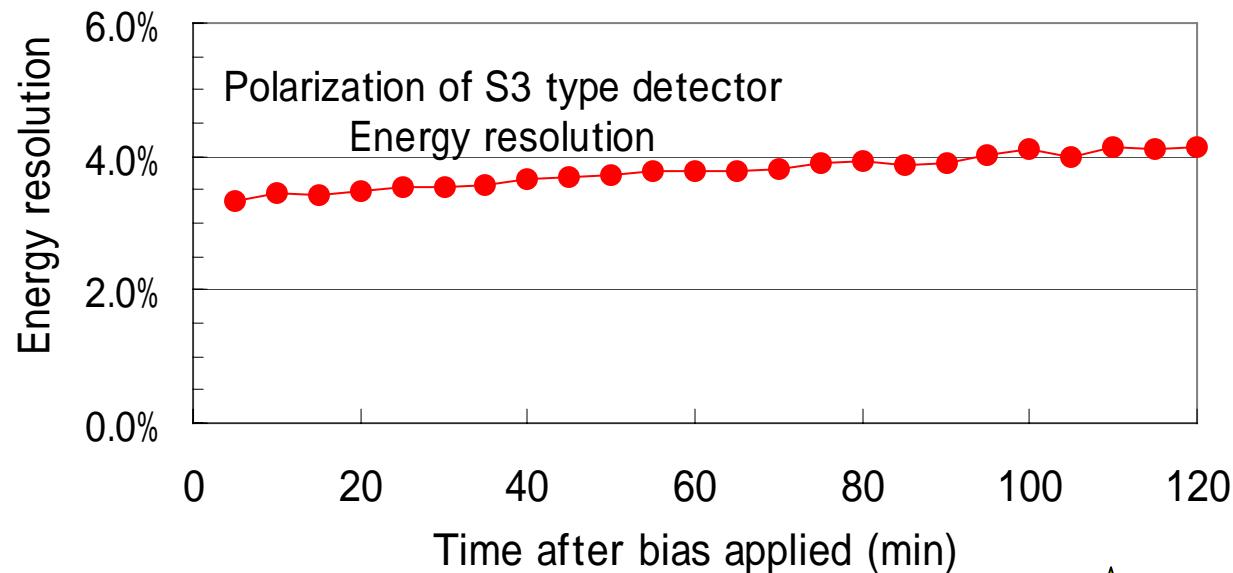
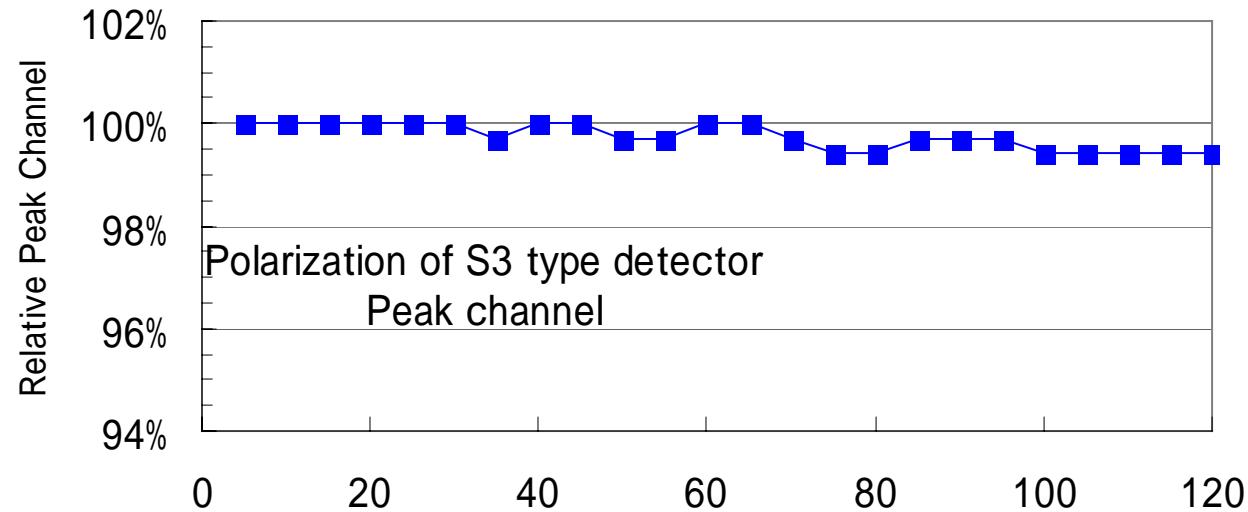


Temperature dependence of S³ type detector



Temperature	FWHM (keV)	Resolution (%)
10	21.2	3.2
25	21.2	3.2
37	20.5	3.1
50	21.2	3.2

Stability of S³ type detector

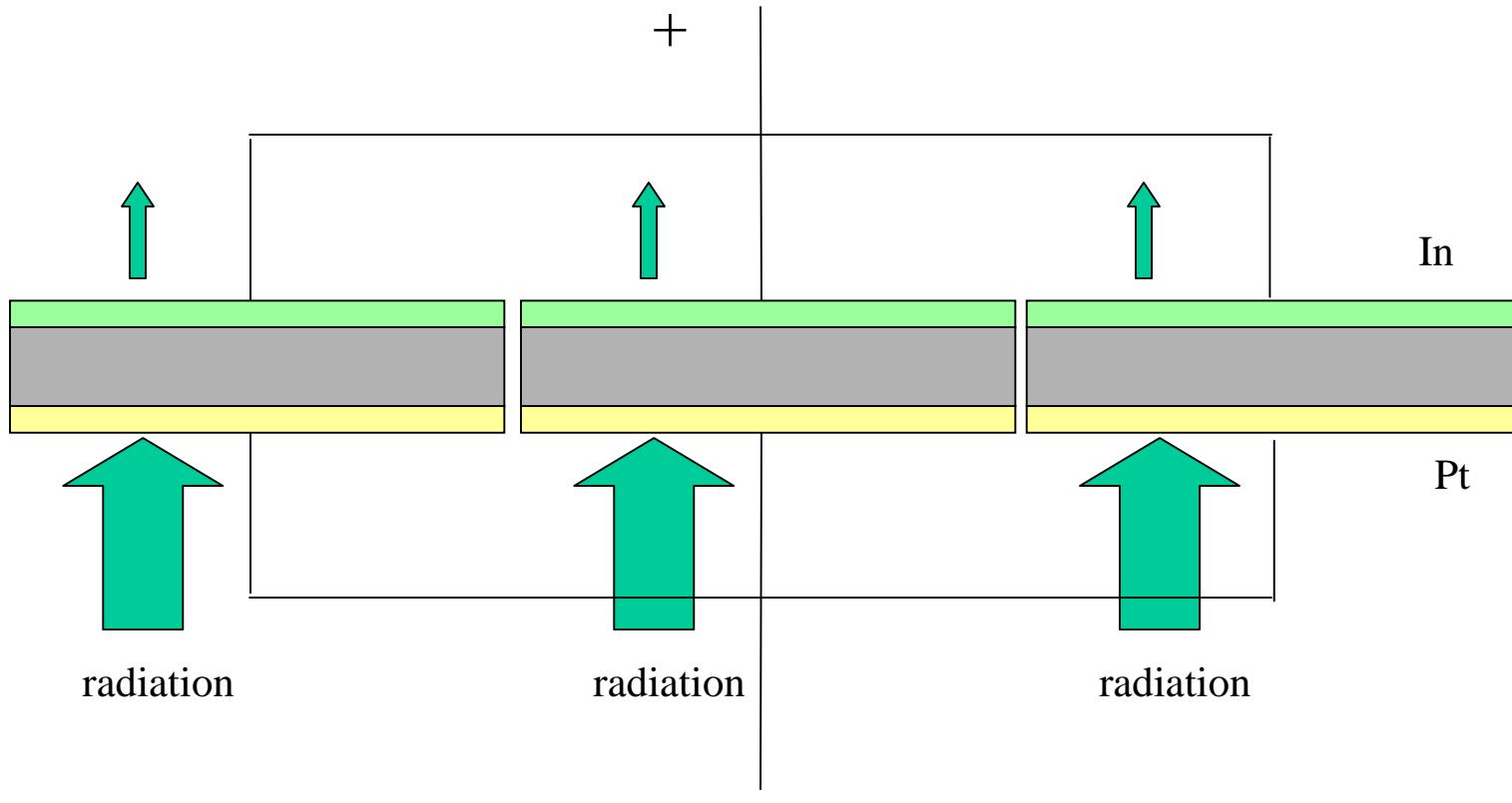


S³ type Summary

- (1) S³type enables the good energy resolution in higher energy with practical stability
- (2) S³type has the potential to increase the volume (thickness) of the detector without increasing the carrier travel length

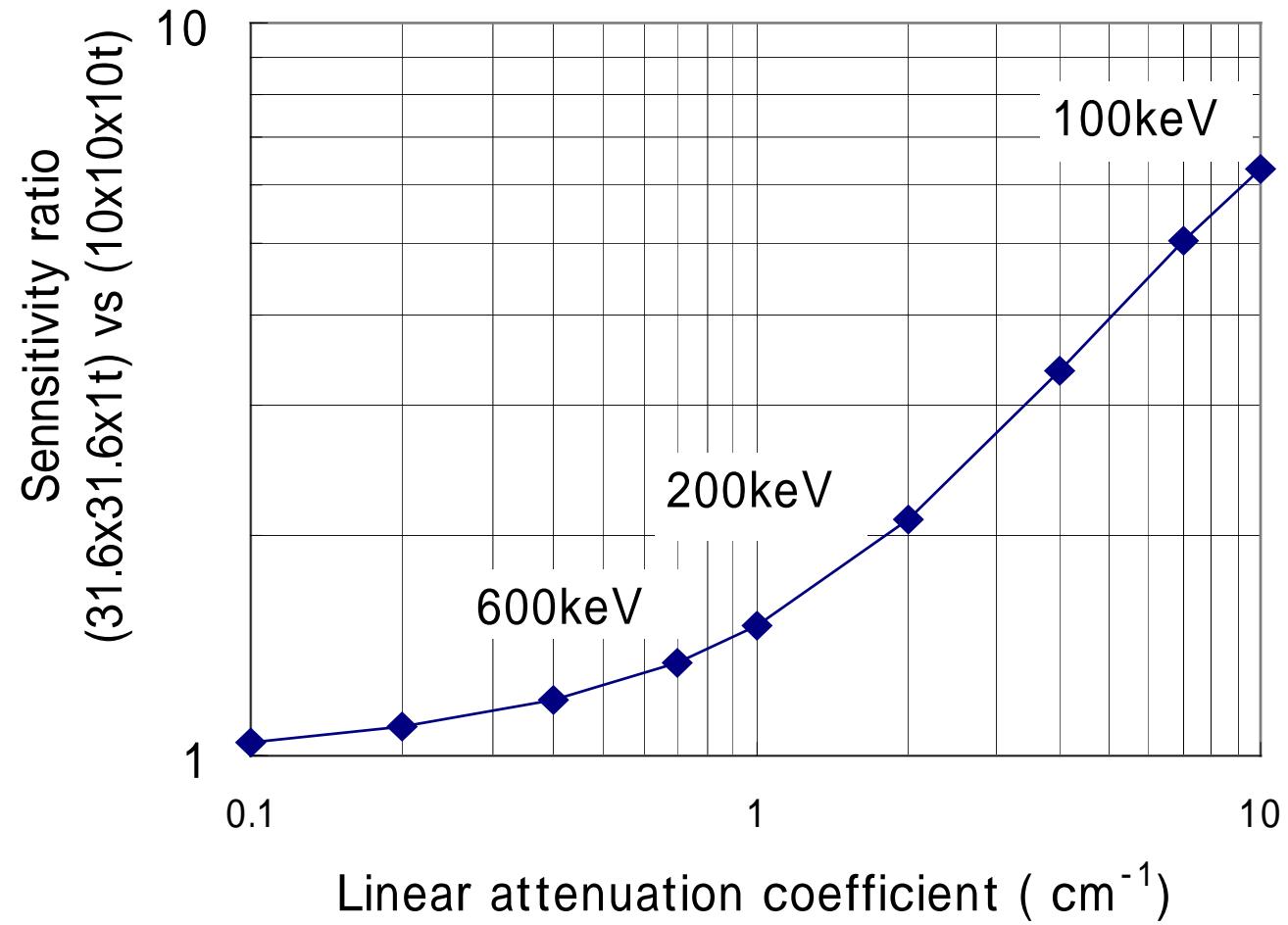


Schottky detector for the higher energy (2)



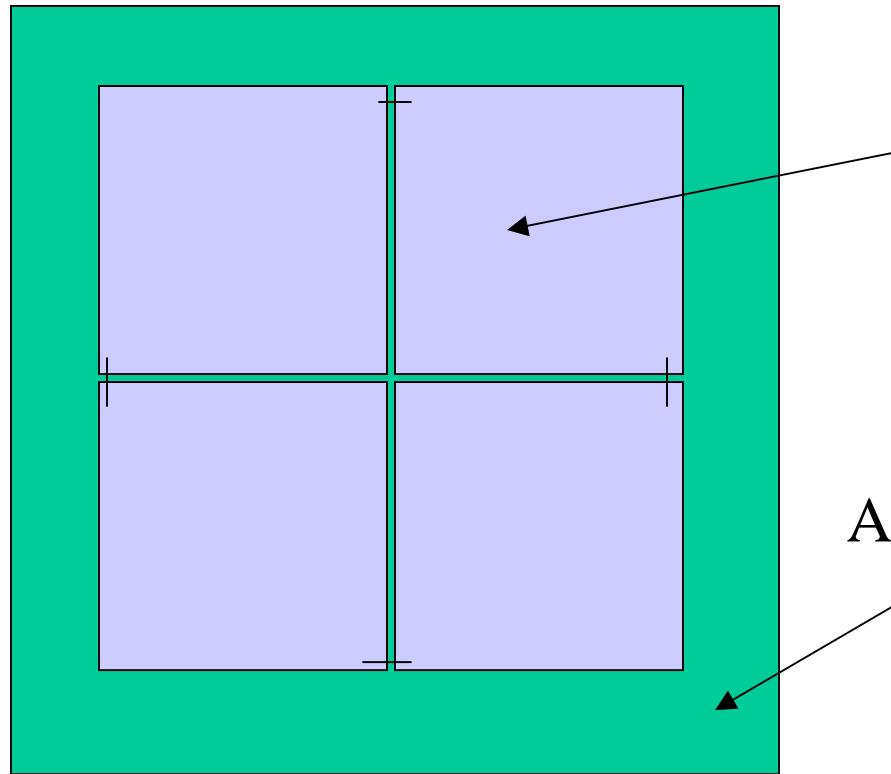
Larger area of detector is simply effective

Sensitivity plane type vs cubic type (1000mm³)



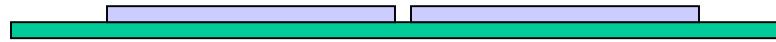
Large area Plane type detector

Detector volume
 900mm^3

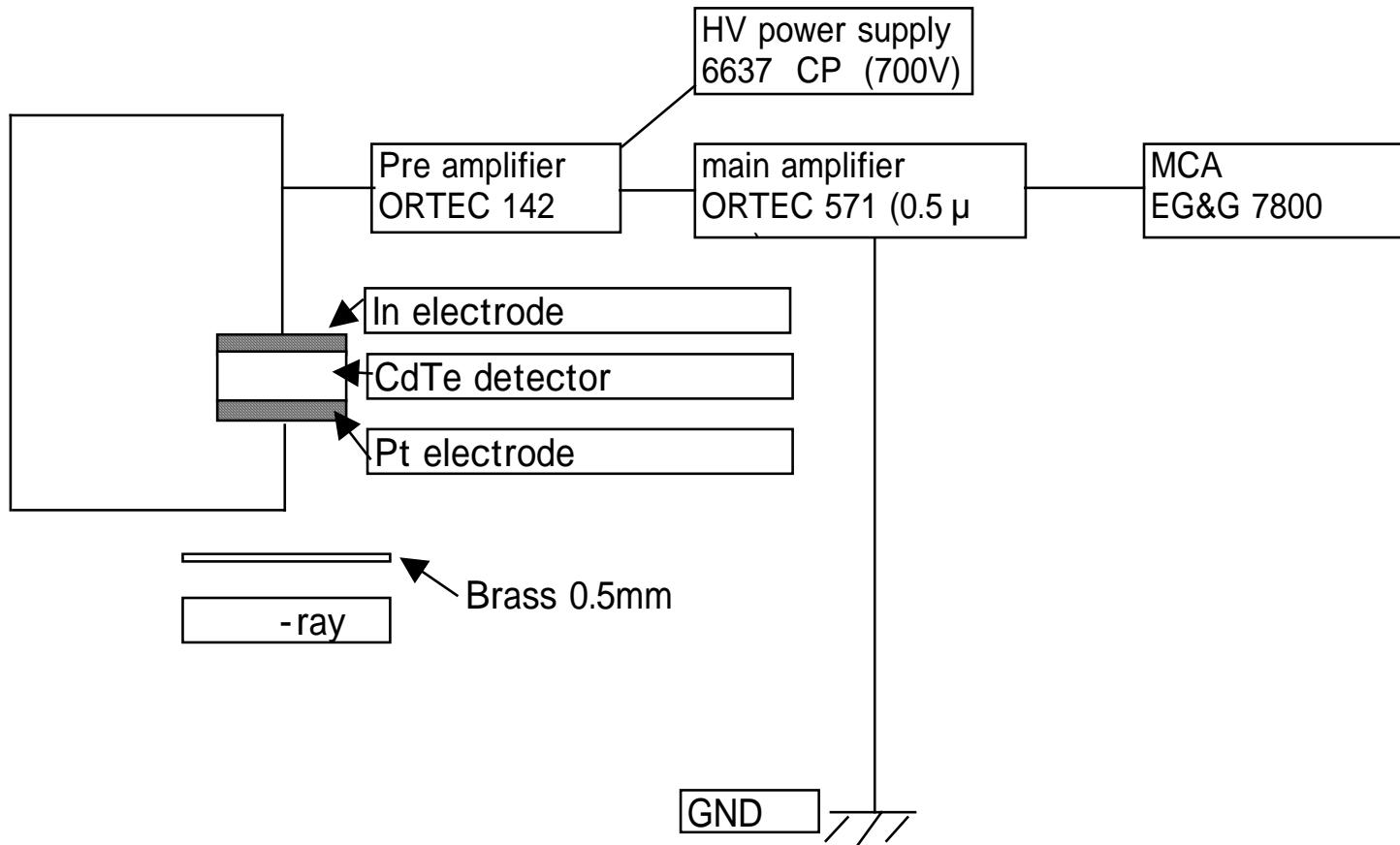


$15 \times 15 \times 1\text{t}$

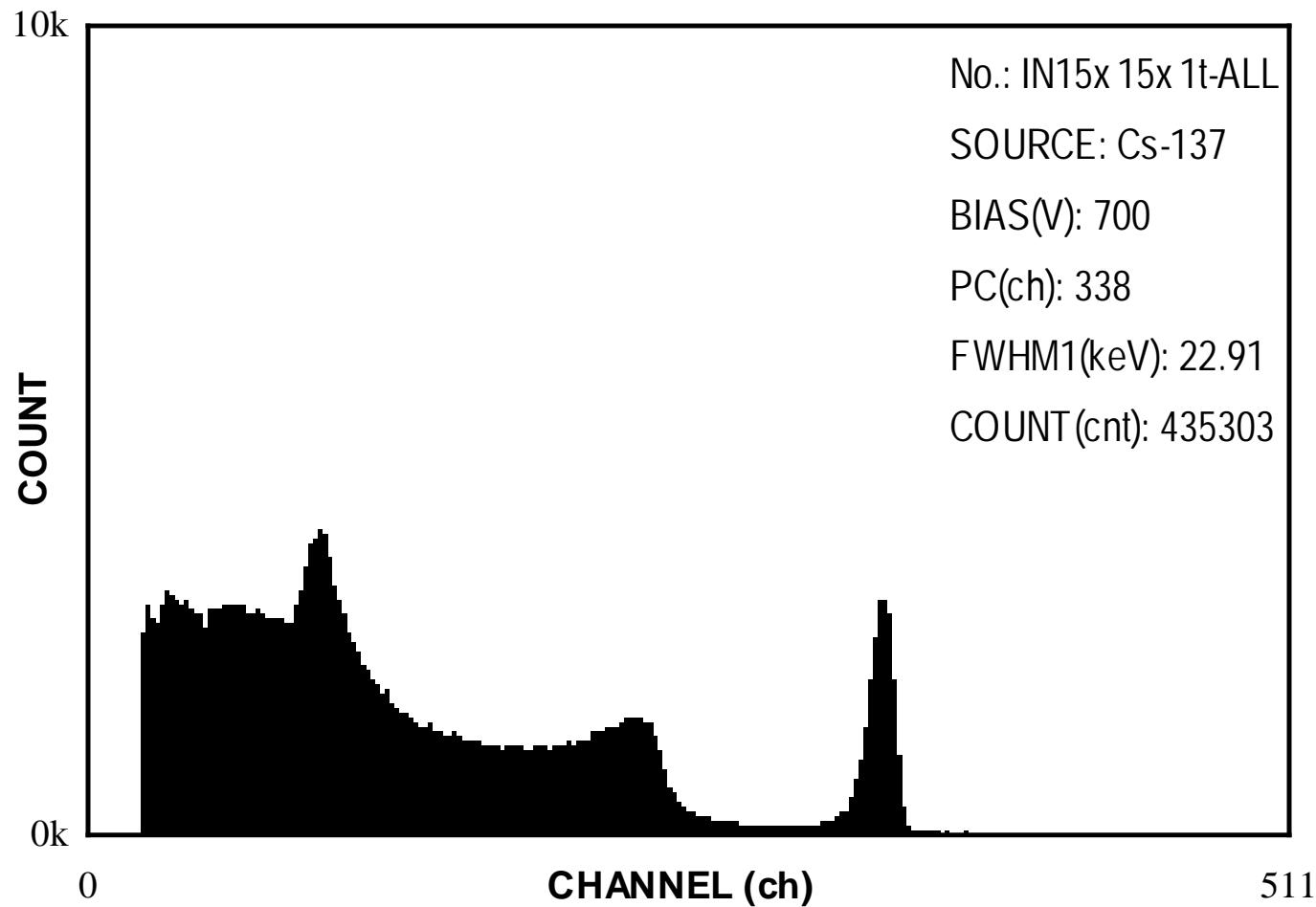
Alumina substrate



Measurement system



Large area Plane type detector



15x15x1t 4pcs together



ACRORAD

Comparison S³ type vs Large area plane type

	241Am			57Co			137Cs		
detector type	PC(ch)	FWHM (keV)	COUNT	PC(ch)	FWHM (keV)	COUNT	PC(ch)	FWHM (keV)	COUNT
Plane type	255	13.3	156,340	257	12	85,256	338	22.9	435,303
Plane type element	255	6.1	38,638	257	6.6	21,110	341	16.0	107,197
S ³ type	253	12.9	24,469	256	12.1	24,834	338	19.6	296,333
Count ratio (*) Plane type/S3 type			6.4			3.4			1.5

Plane type : 15x15x1t 4pcs together (900mm³)

Plane type element : 15x15x1t 1pcs

S³ type : 10x10x10t (1000mm³)

* The distance from the source is 20mm

Large area plane type : better sensitivity (especially at low energy)
almost same energy resolution



Large area plane type Summary

- (1) A 30 x 30 x1mm CdTe detector (900mm^3) was fabricated.
- (2) The detector showed almost same energy resolution and higher sensitivity compared to 10x10x10mm detector.

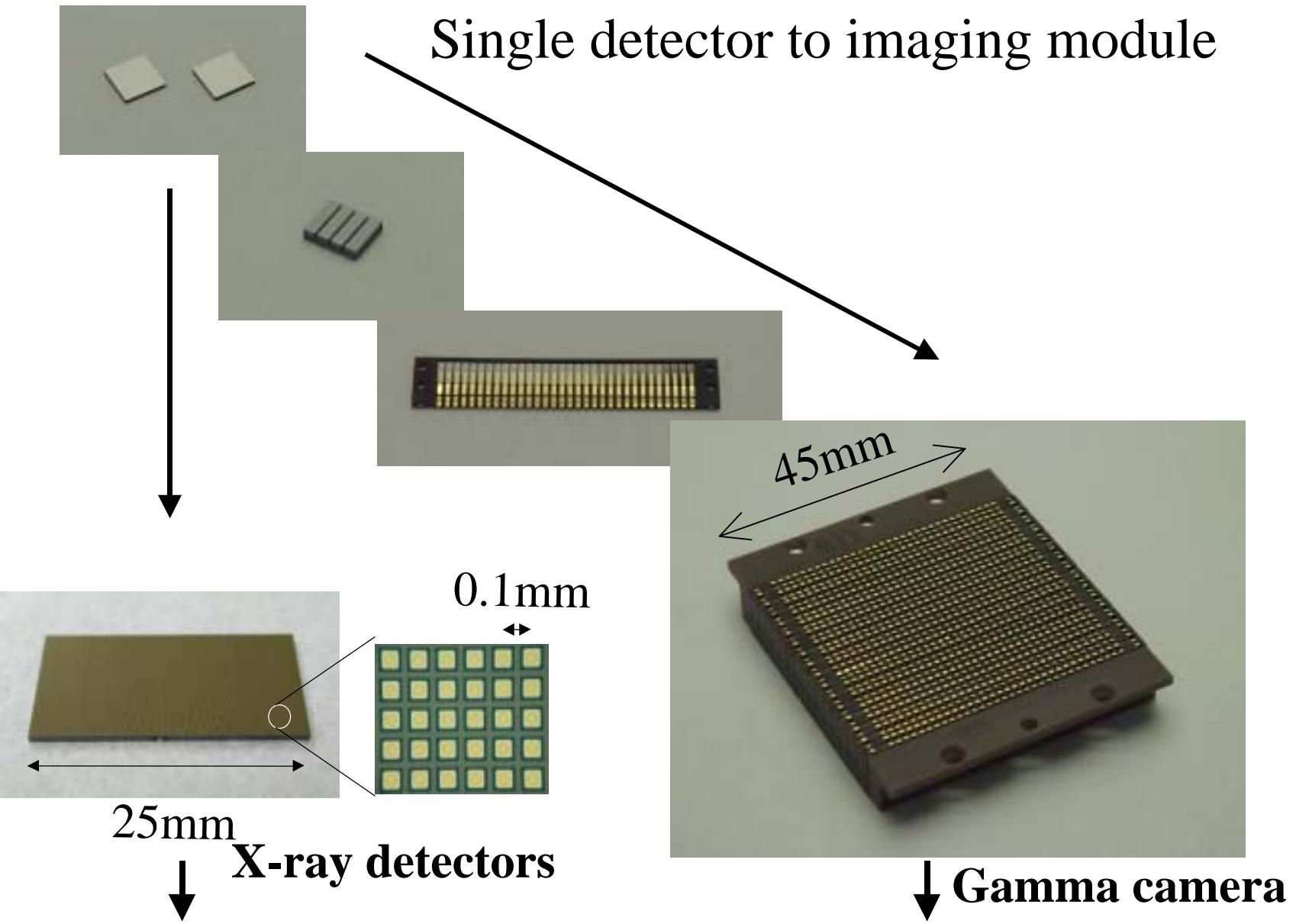


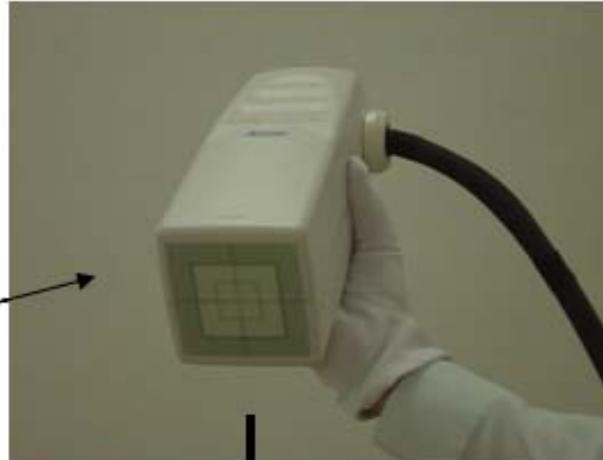
Imaging Detectors /devices



Photos by courtesy of Okinawa Convention & Visitors Bureau







Mini gamma camera
MGC500
(FDA approved)

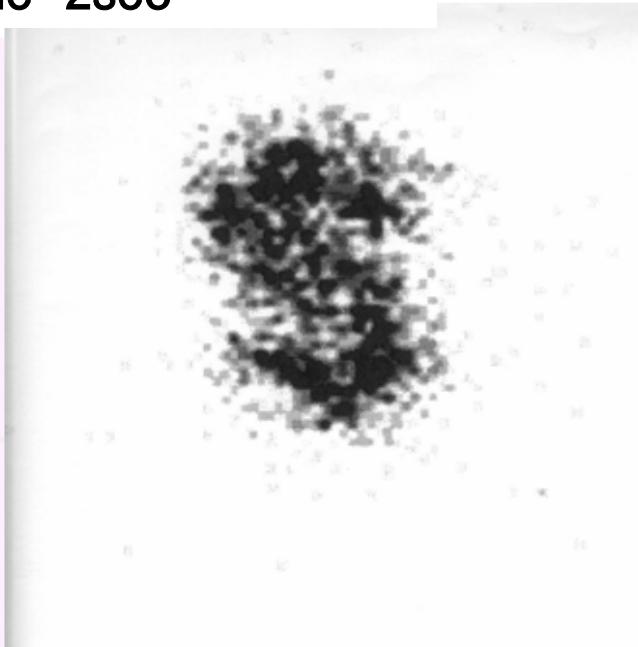


ACRORAD

Comparison of gamma image

(99mTc is filled in a plastic tube)

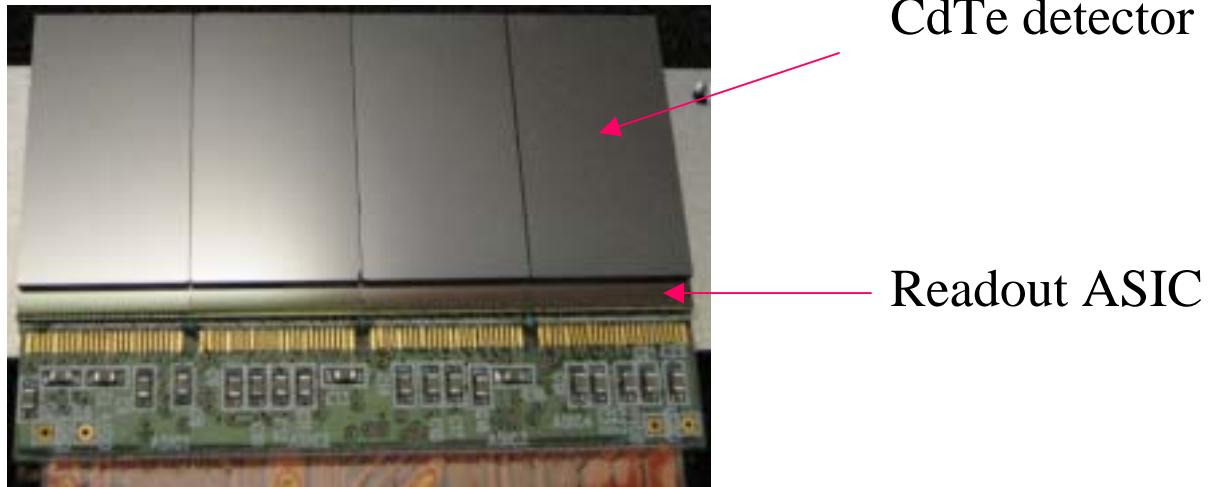
Collection time 2sec



1cm



Development of CdTe X-ray imager

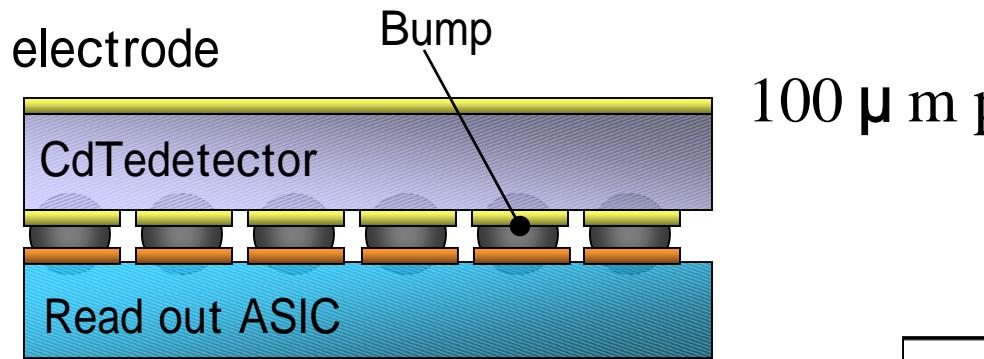


Pixel pitch : 100 μ pixel pitch

Number of pixel : 120k

FOV : 25mm x 50 mm

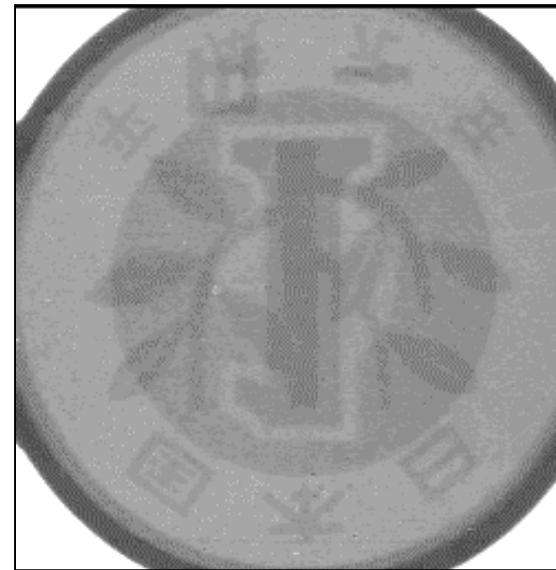
CdTe X-ray imaging hybrid



¥1 coin (aluminum)

High contrast

High spatial resolution

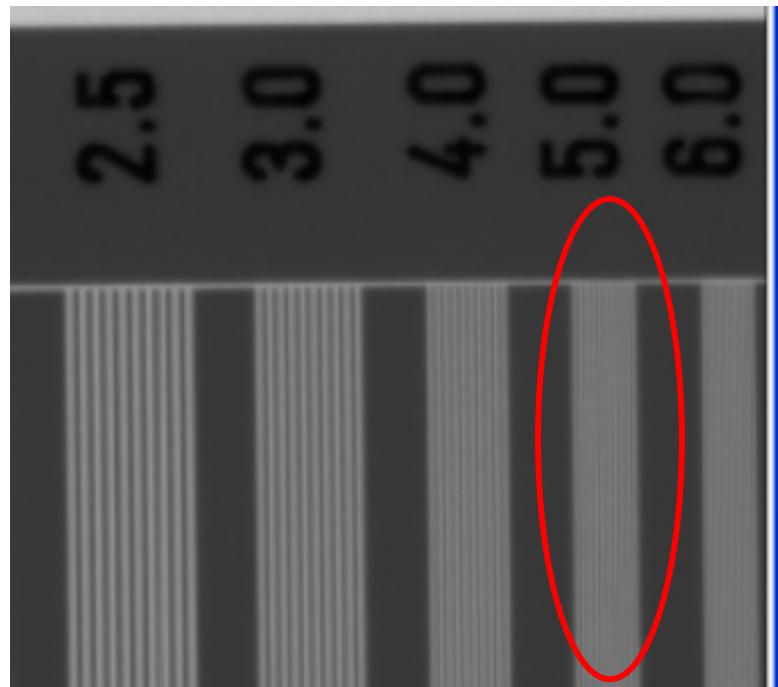


Resolution

Test chart image (60 kV 50 μ A)

CsI(indirect conversion)

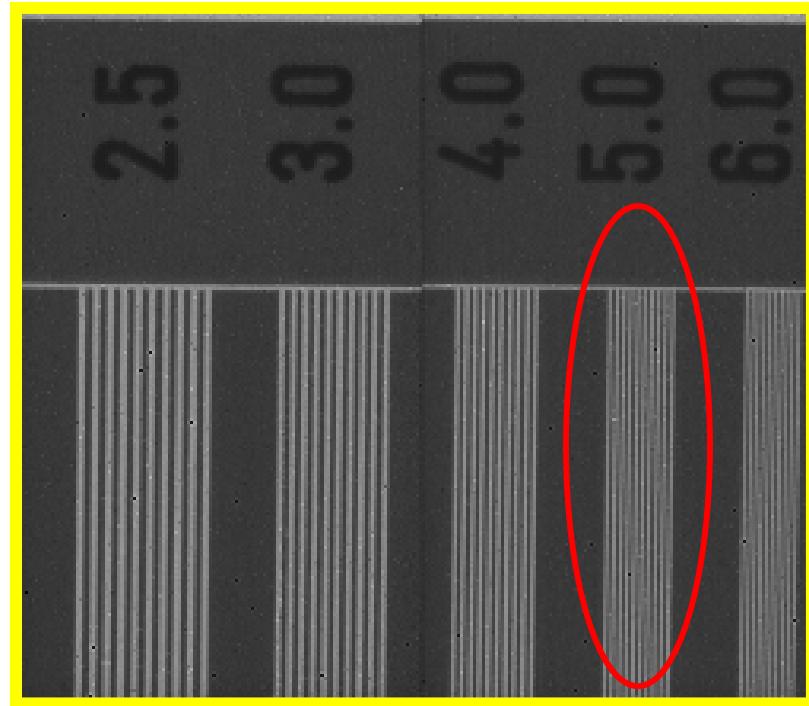
pixel pitch 100 μ m



* with image correction

CdTe(direct conversion)

pixel pitch 100 μ m



* without image correction



Imaging detector /device summary

(1) Mini Gamma Camera was developed

the high sensitivity and high spatial resolution were demonstrated

(2) CdTe/readout ASIC hybrid for the X-ray imaging is being developed

Better resolution than CsI FPD was demonstrated

Large and homogeneous CdTe single crystal wafer is suitable for the x-ray imaging device



Thank you for attention !

CdTe detectors
ACRORAD



Photos by courtesy of Okinawa Convention & Visitors Bureau



ACRORAD